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VOL. XVII No. 65

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ARTICLES

Defence against the sea, *by Professor J. A. Steers* 7
Teaching science to juniors by the discovery method, *by N. F. Newbury* 16
Time to react, *by D. E. Broadbent* 21
Chemistry and Clothing, *by Dr. J. W. Bell and Professor C. S. Whewell* 26
Problems of the moon, *by Patrick Moore, F.R.A.S., F.R.S.A.* 33
The road and rail question, *by Sir Reginald Wilson* 47
The evolutionary significance of human hair patterns and skin colouring, *by Dr. C. B. Goodhart* 53
Challenges to agricultural research, *by Sir William Slater, K.B.E., F.R.S.* 60
Some aspects of crystal physics, *by Professor G. F. J. Garlick, Dr. R. V. Hesketh and Dr. E. E. Schneider* 66
The recent development of Greater London, *by A. G. Powell* 76

MEMORANDA

A Message from the President 1
Notes and Comments 2
British Association News 43
Echoes from the past 64
Looking at Science 87
Books 89

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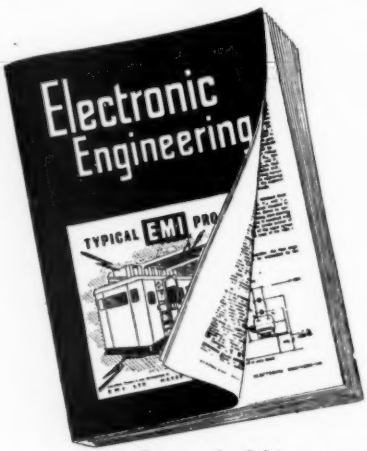

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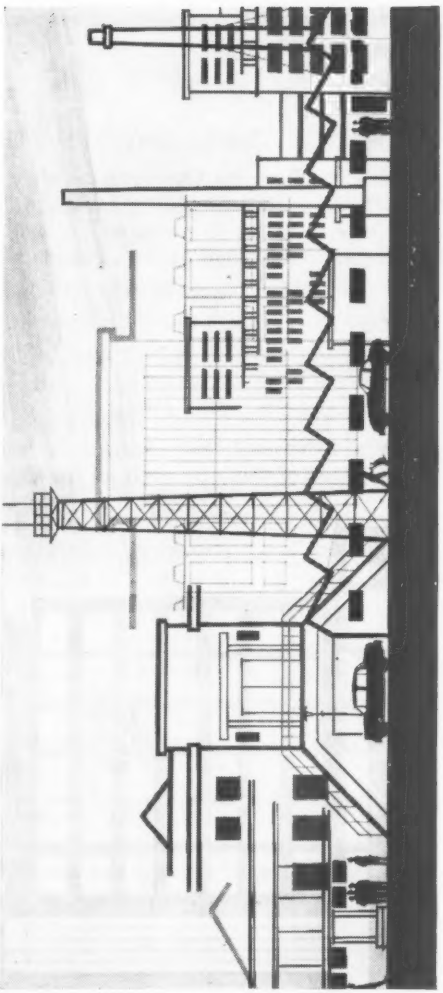

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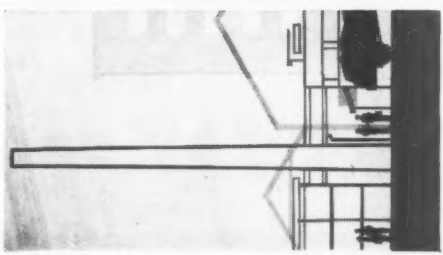

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A Message from our President

In the modern world science grows more and more important, both as a source of fundamental ideas affecting thought and as the basis for the technology on which civilisation depends. In the past fifty years the advance of science both in facts and ideas has been greater than ever before. Unfortunately scientists have been less successful in sharing this advance with non-scientists and even with one another. The proportion of educated people with a reasonable appreciation of contemporary science has hardly risen in the last century and may even have fallen, while it has become progressively harder for a man working in one branch of science to have even a cursory idea of what his colleagues are doing in the others. For these reasons the British Association in recent years has devoted the bulk of its efforts to the diffusion of science. One of the most promising ways of doing this is by publishing accounts written by leading scientists of important advances in their fields, and the Council of the Association have therefore decided to increase the scope of *The Advancement of Science*, issuing six numbers a year instead of four and including, in addition to some papers given at the Meetings, others written specially for it, as well as notes and comments on matters of interest and reviews of books and films.

This first issue of *The Advancement of Science* in its new form reflects an entirely new editorial policy agreed upon by the Council as a background to their new and continuing campaign in the presentation of science to lay audiences all over the country and throughout the year.

The journal is designed to reflect—as do the Annual Meetings—progress in the whole field of science. While it will contain articles of specialist scientific interest it will be essentially a non-specialist journal which will attempt to inform scientists of the progress of work in disciplines other than their own and to interest students, upper form pupils of schools and laymen who are anxious to understand something of the significance and the impact of scientific research and development.

G. P. THOMSON

Notes and Comments

Decimal Coinage and the Metric System

In his preface to the Report, published this month by the Association of British Chambers of Commerce and the British Association for the Advancement of Science, Sir Alexander Fleck says:

'This Report is a down-to-earth contribution on a very complex series of subjects. The debate on many aspects of the questions will continue but, as a result of this Report, we are now brought appreciably nearer the time when specific recommendations by appropriate legal authorities will and should be made with an assurance that they will find a large measure of acceptance. When that time comes this Report will justifiably be looked on as a very worth while contribution to greater technological and social efficiency.'

Both Associations set up, quite independently of each other, two special committees to investigate the desirability, the practicability and the costs of introducing a decimal coinage and/or a metric system of weights and measures in this country. However, the two Committees agreed from the beginning to carry out a joint investigation and have produced a unanimous report. It is estimated that over 2000 organisations have submitted evidence towards compiling the report and that it is, therefore, the most thorough and far reaching investigation into the subject ever made in this country.

The cases for or against adopting either decimal coinage or the metric system or both are considered in detail. The Committees' attitude has been objective. No assumptions were made that either a decimal coinage or a metric system of weights and measures was superior to the systems existing in this country. The intention was to present the facts, and to weigh the evidence carefully and impartially so that a dispassionate judgment could be made.

The Committees have been concerned with the implications and consequences, both international and domestic, and the costs of a change-over, to the United Kingdom. Further, they have also considered, in the event of the adoption of a metric system appearing impracticable, the advantage of increased rationalisation or decimalisation of the present units of weights and measures.

The report is divided into four parts, with appendices:

I. Decimal Coinage

The first part deals with the problem of decimal coinage, outlining previous enquiries carried out in this country, the reasons for the present enquiry, and the implications of a change. The costs of changing over to a decimal system have been estimated, and these costs are compared with the long-term benefits which would flow from a change. The various methods of decimalising our coinage are then considered in detail.

The main recommendation is that there is a strong case for adopting a decimal coinage in this country. The Committees recommend that the Government should take an early decision, since the longer the delay, the greater will be the transitional costs if the change is eventually made. The preparatory period might be 3–5 years with about 2 years for the actual transition. Before taking such a decision the Government must, of course, sound public opinion, and must also decide on the most suitable system, bearing in mind that there is an overwhelming wish to maintain the £ as the main unit. If the £ need not be retained, a system based on a 10*s*. unit should be seriously considered.

II. Metric System of Weights and Measures

The second part of the enquiry deals, in similar fashion, with the metric system, outlining previous enquiries and the present position and trends within the U.K., Commonwealth and U.S.A. in metric usage. The international aspects are discussed, as is the problem of international standardisation and the difficulties which would be experienced by some sections of British industry. The cost factors of transition are also discussed. The predominance of engineering production in non-metric units and the international usage of non-metric units in certain spheres is also mentioned. There is, however, a general feeling that the metric system will in course

of time become more widely used in the U.K. and the rest of the world. The Committees therefore recommend that the Government should keep watch on the world situation and institute regular two-yearly reviews in consultation with industry and commerce and in conjunction with corresponding bodies in the Commonwealth and U.S.A.

The Committees are unable to recommend compulsory change over to the metric system in the immediate future because the benefits appear to be small and outweighed by the extremely high transitional costs, particularly in engineering. However, practice in the use of the metric system and decimal thinking should be encouraged to enable the U.K. to keep abreast of the world trend.

III. Improving the Imperial System

The Committees then suggest some of the improvements which might be made to the existing system of weights and measures. The recommendations made in the Hodgson Report, 1951, are examined and the outline of a national policy of improvement is suggested.

IV. Educational Aspects

The final section of the report discusses some of the educational aspects of a change in the system of coinage and weights and measures. The savings that could be made in education are estimated, and it is recommended that in any event much greater emphasis should be placed on the teaching of decimals in schools.

Appendices

The first two appendices give some extracts from the evidence received on decimal coinage and the metric system respectively. A third groups the countries of the world by the predominant system of weights and measures; another appendix includes the questionnaires sent out by the Committees.

Copies of the report entitled 'Decimal Coinage and the Metric System—should Britain change over?' are available from booksellers or Messrs. Butterworths, price 7*s.* 6*d.*, or from the Association of British Chambers of Commerce, 68 Queen Street, E.C.4.

"15 to 18": The Crowther Report*

This Report must be the best piece of sustained writing about education which has appeared since the end of the War. How much it is a child of the times may be seen by comparing it with its great predecessors, which were fathered by Hadow and Spens. These reports were clad in mass-produced grey covers and their names were mostly abstract nouns. The Crowther Report calls itself by numbers and has appeared in a *haute-couture* garment of terra-cotta and off-white. The vital statistics consist of 446 pages of the Main Report, 26 pages of summary findings and arguments, and an indefinite number of appendages, most of which consist of a baggage train of statistical evidence, which is to appear as a separate volume and which has not yet caught up with the film star herself. It will be seen that the waist is still a manageable armful; by the intelligent use of this excellent summary the delights of the main body of the report may be explored at leisure. One of the members of the Council, A. B. Clegg, has actually been doing this; he has published for the West Riding Authority a collection of telling facts, culled from the Report. As the years go by the Report may rival *Hamlet* as a publication full of quotations.

The nature of the Advisory Council's scientific outlook may be inferred from the complaint in their concluding remarks that, notwithstanding the vast amount of material they have handled, they were short of statistics and research material. The film star complains, on the arrival of her baggage train, that she has had to come without the very hat she wanted.

The central conclusion of the Report is that, after the passing of fifteen years, the provisions of the Education Act of 1944 were entirely sound both in principle and in detail, and that the most effective steps the country can take will be to carry out the provisions of the Act, with all possible speed. This conclusion, coupled with the recommendation that the first major reform to be carried out should be the raising of the school-leaving age to sixteen not later than 1968, is particularly valuable at the present time. The present decline in the idealism which inspired educational thinking immediately after the War, the emphasis on technical competence, value for money and on education as a national material

* Report of the Central Advisory Council on Education.

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* Report of the Central Advisory Council on Education.

investment, the weariness of ageing educationists who have carried through unprecedented educational advance in the last ten years, the practical fears of some teachers who cannot believe that staffing ratios will ever be 1 in 17, or thereabouts, are leading to a weakening of faith in the belief that all may benefit from full-time education to the age of sixteen. The renewal of faith in this reform is perhaps the greatest contribution of the report; but the courses, the buildings and the teachers must be here in time if it is to be a success. For these reasons it can hardly take effect before 1968.

The chapters on the sixth form are a fascinating record of the way in which English life and scholarship are trying to come to terms with the scientific revolution. Shallowness of study is firmly rejected; specialisation will bring out the best in a man, provided he will make himself both literate and 'numerate'. 'Numeracy', a word which Sir Geoffrey Crowther has claimed for himself, is a state of knowing something about scientific method, of having a knowledgeable respect for quantity and the achievements of science. To achieve numeracy in the nation has in recent years been one of the main aims of the British Association for the Advancement of Science. The enrichment of the academic courses in secondary schools which the Council would like to see, will not be achieved without a substantial improvement in teaching power, both in scholarship and in the craftsmanship of teaching. It may be that a staff composed partly of good scholars from the universities and partly of those who will have had the advantage of three-year training as teachers, could do all that the Report envisages provided they could bring themselves to work together in a common cause. It was not within the terms of reference of the Council, but one would like to see a complementary report on the quality and quantity of university teaching to match the chapter on the staff of the sixth form.

Perhaps the weakest section of the Report is that on County Colleges, because so little is known about them. A great deal is known about day release and voluntary continuative education, and the Report, unlike some of the advocates of priority for County Colleges, realises that compulsory part-time education calls for a new and pioneer approach. For this reason, controlled experiments are proposed. It is to be hoped that such experiments will take place in areas which are educationally and industrially sympathetic to the work, and not in areas with problems of unemployment to solve in the years when greatly increased numbers of pupils leave school.

There is a salutary review of the various forms of technical education, which, in spite of its post-war growth, is not well co-ordinated and often wasteful. The newer forms of scientific gardening are advocated for this field of endeavour; a careful preparation of the ground for the particular crop intended; the choice of a good strain of seed; planting to minimise thinning out, and a pattern of growth which will lead to early maturity.

This Report can be the constant inspiration for many years, of all those engaged in education whatever their age; it will be of special value to the younger leaders who must shortly take over from those who have borne the brunt of the battle since 1944. Sir Henry Hadow's report advocating reorganisation of schools was published in 1926; we are still struggling to complete that reform by 1965. Sir Geoffrey Crowther, the ex-editor of the *Economist*, has harnessed and bridled his facts and his Committee to convince us that if we have the will, the nation's economy can carry his major proposals without difficulty within ten years, and most of the rest within twenty.

H. OLDMAN

Should Geology be taught in school—a comment on university requirements*

The geological report recently issued by the Geography and Geology Panel of the University of Birmingham Enquiry into 'A' level courses and entry requirements of universities is a clear and thoughtful document. Going beyond the original terms of reference the Report considers whether universities might start their courses in geology at a higher level than at present if the 'A' level examinations were of a more uniform standard.

Such a consideration raises certain problems. Firstly, as the report rightly concludes, it is necessary for intending students in geology to have a wide education up to 'O' level, especially in languages. Thereafter they should receive a thorough grounding in basic sciences, which should be carefully

* *Report of an Enquiry into the suitability of the General Certificate of Education Advanced Level Syllabuses in Science as a Preparation for Direct Entry into First Degree Courses in the Faculty of Science. University of Birmingham, September 1959.*

chosen with respect to the students' background, together with the often forgotten exercise of expression in good English. Such a conclusion is applicable to all the sciences in these days of ever-increasing specialisation and fragmentation.

It is apparent from recent statements from the Government that within the next few years considerable expansion of the universities will be accomplished in order to train the numbers of scientists and technologists that the country requires. Upon the schools therefore rests the responsibility of turning out more and more young men and women who are not only educated but capable of independent study. The schools are fully aware of their responsibility, but their labours are to a large extent thwarted by the bogey of examination requirements which may inevitably lead to 'spoon feeding' rather than to training of the mind.

It is, unfortunately, all too frequently apparent among first-year students that the capacity for individual study has not been developed. Therefore, as far as geology is concerned, would not the future situation be best met by following the recommendations of the Panel which emphasise the cultural value of geology as a subject at least to 'O' level, and by making four-year courses the rule rather than the exception at the universities, thus enabling the student to have more time for reading both of a general and specific nature. This alone will make what is required in this new age—a combination of an educated man and a first class scientist.

The University, Sheffield. A. E. CURRALL

The Indian Science Congress

The 47th Session of the Indian Science Congress was held in Bombay from January 3 to 9, 1960, and I was happy to be the representative of the British Association on that occasion. In recent years each Session has been inaugurated by the Prime Minister, Mr. Jawaharlal Nehru, and consequently the proceedings differ somewhat from those of the Annual Meetings of the British Association, as the presence of Mr. Nehru introduces a note of direct governmental interest in the proceedings and in the development of pure and applied science.

The Congress was welcomed by Shri Sri Prakasa, the Chancellor of the University of Bombay. A very interesting Inaugural Address was delivered by Mr. Nehru. He spoke under some difficulty, for the opening meeting was held in a large pandal, or open marquee, which was in two parts. The overseas Delegates occupied a platform in one part, while the main audience occupied the other, larger, part. Unfortunately, there was a wide gap between the two parts, and in it Mr. Nehru was exposed to the sun during most of the proceedings. In the course of his speech, Mr. Nehru said that he was more concerned with the social consequences of science than with science itself. India was faced with major problems, political and economic, and in the main these were of a social nature. The increase in the population and the need to raise the standard of living presented a vital problem and one which India could not solve without recourse to science. He mentioned also that, while in a small way India was making jet aeroplanes, the bullock cart was still in the streets of Bombay, and that he sought the help of scientists—by the production, for example, of atomic power at a competitive cost—in the task of raising the standard of living of the overwhelming majority of Indians who lived in villages remote from the aids and comforts of civilisation.

Prof. L. F. Bates, Prof. P. Parija, Mr. Jawaharlal Nehru.

Professor P. Parija, Vice-Chancellor of the Utkal University, delivered his Presidential Address on 'The Impact of Society on Science', and in a very learned manner examined, with particular reference to India, the factors which throughout the ages have created resistance to the growth of science.

In India and other Eastern countries, he said, the two main inhibiting factors had been 'the authoritarian imposition of dogmas and foreign invasions. The former canalised human thought while the latter created a sense of insecurity and subdued the

free play of human curiosity which is the basis of all scientific activity. Chief among the historical events which led to intellectual freedom in Europe were the voyages of discovery, the conquest of Byzantium by the Turks, and the Industrial Revolution. Similar events did not occur in India since the social organisation and the economic system were such that the incentive for revolutionary change did not exist. When, however, there was lasting peaceful contact with the free-thinking world, an age of intellectual freedom was ushered in. Those Indians who responded to this liberalising influence have made notable contributions to scientific advancement. Freed from restrictive social influences, the Indian mind is as capable of effective scientific thinking as any Western mind.'

An Exhibition of Scientific Instruments and Industries, arranged on similar lines to that of our own Physical Society Exhibition was officially opened in the afternoon by Shri Y. B. Chavan, Chief Minister, Bombay. Great attention was paid to scientific apparatus now being manufactured in India. I was impressed by the quality of much of it, although I felt that in some cases insufficient allowance was made for the wide range of temperature to which it was likely to be exposed. In the same building the British Council had arranged a large and pleasing display of British books.

I attended Section III, Physics, on the following day to hear the Presidential Address by Professor S. Parthasarathy on 'Sound and Heat'; it was read by one of his colleagues in the unfortunate absence of the President through illness. In the afternoon, at a Convocation of the University of Bombay, an honorary degree was conferred on Professor Niels Bohr.

I had been asked to give a lecture of general interest to Section III, and on January 5, I spoke on 'The Visualization of Magnetic Processes' to a packed and overflowing audience. I was promptly asked to repeat it, and deliver other lectures as well, in several Indian universities and research institutions. Section III met in K.C. College, and as an example of the contrasts one finds in India, I mention that in the construction of a large ferro-concrete building adjacent to the College, water was being carried into the building in bullock skins.

I visited the Tata Institute of Nuclear Research in Bombay, its new research laboratories at Colaba Point where considerable attention is being paid to low temperature equipment and to magnetic resonance experiments, and the Nuclear Energy Establishments at Trombay, and was much impressed by the work which Professor Bhabha and his colleagues are doing.

There were many popular local excursions during the meeting, such as the one to the Aarey Dairy Farm, where one could see in operation a most interesting experiment in co-operative dairy farming. There were excursions to Elephanta, and many of the Delegates went on a two-day excursion to the caves of Ellora and Ajanta after the close of the Session. We then dispersed, many of us to visit a number of university and research institutions. I delivered lectures in Bombay, Madras, Bangalore, Calcutta, Delhi and Poona, and much appreciated the opportunity of meeting and talking with many Indians who were actively engaged in research.

L. F. BATES

Science and Life

Science and Life is a new magazine which is published by Pravda (in Russian) and is devoted to the popularisation of Science. Its sub-title is that of 'a monthly journal of popular science' and the contents live up to this designation, covering a wide range of topics and written at several levels. The main sections of the January, 1960, issue set the pattern for the issues to come. They are: progress and problems of science; the cinema; creative science processes; philosophical questions—here on natural science; science versus religion; historical pages; science and technical news; 'Among books'; and answers to questions.

As with all recent Russian publications the paper and printing are vastly better than a few years ago and the illustrations in this issue are good—some are even in colour.

It is interesting and pleasant to see that although in this number the relationships of the earth and moon are discussed, and such terms as 'apogee' and 'perigee' are explained, there is no preponderance of claims for this aspect of Soviet invention and discovery and that a preceding article on science on the farm is longer.

It will be interesting to see the trend of future numbers, but several of the articles in this issue are excellent, and much lightheartedness is evident in the text and illustrations.

W. E. SWINTON

DEFENCE AGAINST THE SEA*

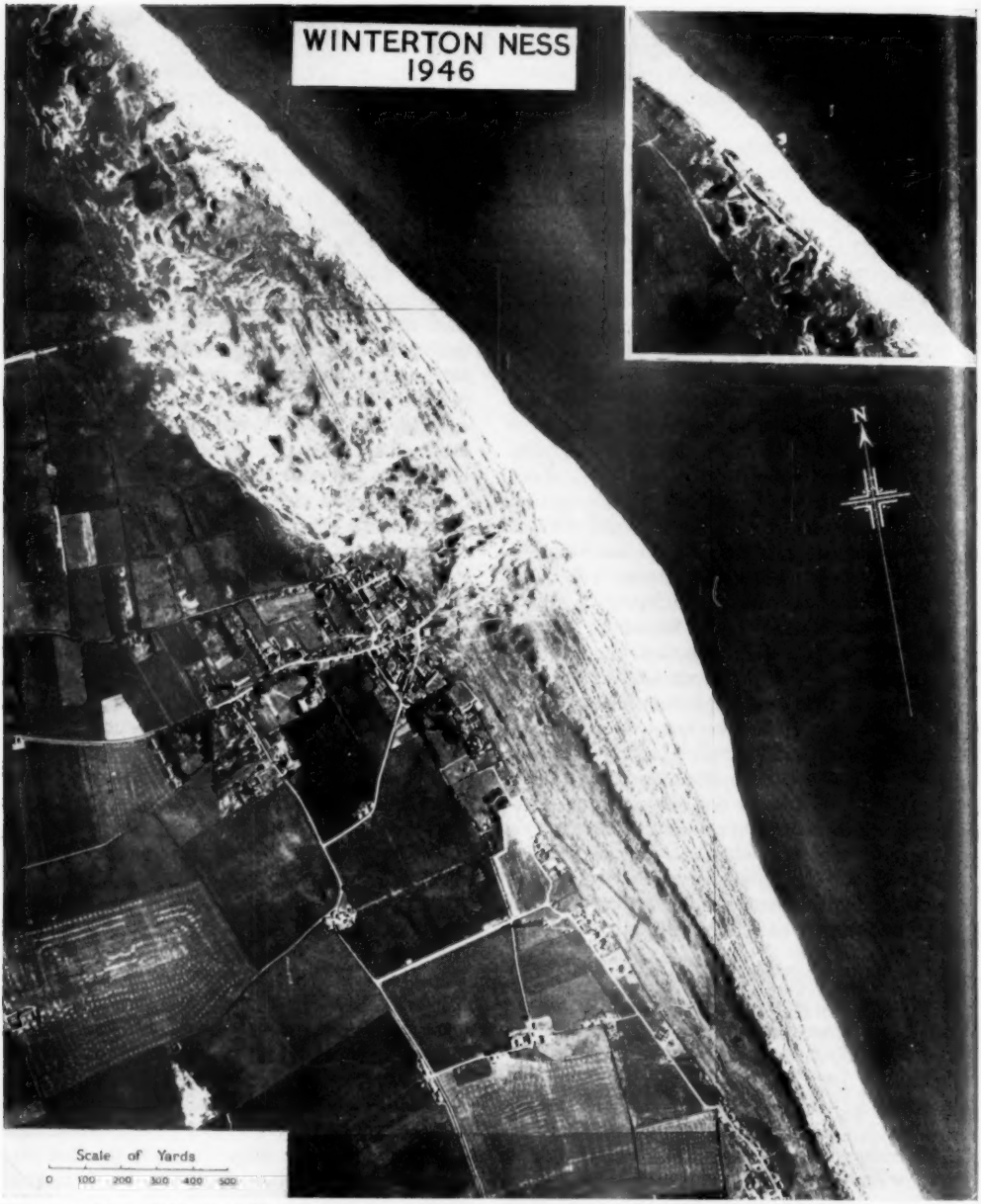
By Prof. J. A. STEERS *Department of Geography, University of Cambridge*

Dwellers on the coast have always realised something of the work of the sea in eroding cliffs, in building beaches, in the formation of sand and shingle forelands, and in the growth of salt marshes. The comprehensive and interesting reports of the Royal Commission on Coast Erosion and Accretion,[1] the final one of which was published in 1911, certainly made known to those interested an enormous amount of information about our coast, but relatively little active work of any sort followed as a result of it. It was not until the great storm of 1953, and the severe salt-water flooding it caused, that the country as a whole realised something of the problems facing the engineer and the scientists who are interested in coastal studies of one kind or another. People everywhere then became conscious of the potentialities of storm surges both on low-lying coasts and along stretches of easily eroded cliffs. Many too, perhaps for the first time, appreciated that both sea-level and solid land are subject to vertical movements, and that parts of our coast are sinking relatively to sea-level, whereas others are rising. The two short, but effective reports of the Departmental Committee on Coastal Flooding,[2] under the Chairmanship of the late Lord Waverley, brought home the necessity of national, as distinct from local, planning of sea-defences, and led also to the formation of two standing committees, that on sea defence problems under the chairmanship of Mr. E. A. G. Johnson, of the Ministry of Agriculture, Fisheries and Food, and the other under the direction of Prof. J. Proudman, concerned mainly with tidal phenomena. The surge of 1953 affected mainly the east coast; surges can and do occur elsewhere, but are likely to do more damage in the North Sea, if, as in 1953, circumstances of wind, storm, and tide are favourable. Moreover, there is a greater proportion of soft cliffs, and of low dune and shingle coast on this side of Great Britain than elsewhere, so that it is far more vulnerable. Serious erosion also occurs at various places on the south coast, especially near Selsey and Milford-on-Sea. Nor is the west coast inviolate.

For administrative purposes the Ministry of Housing and Local Government is responsible for the defence of cliffed coasts, and that of Agriculture, Fisheries, and Food for the remainder. There is, of course, coordination between the two for those parts where one type of coast passes into the other. In Scotland, the Secretary of State, acting through appropriate officials at St. Andrew's House, Edinburgh, is the responsible authority.

Erosion and accretion should always be envisaged as national problems. Erosion is usually far more spectacular, and often destructive of property and perhaps life. The Royal Commission in its final report showed that, taking the country as a whole, gain was considerably greater than loss. This is still true. But gain of land, by the enclosing of mud flats and salt-marches, is not appreciated by the 'man-in-the-street' in the same way as is the undermining by erosion of cliffs supporting a hotel as at Overstrand or a similar event elsewhere.

* The thesis of the present article by Prof. J. A. Steers arises from a symposium staged at the York Meeting of the British Association under the title of 'Coastal erosion and coast protection'. Four papers—introduced by Prof. Steers—were given in the symposium. The papers, which aroused a great deal of interest, at the time and have since been reported in *Nature* (184, 1959, 499), were as follows: 'The biology of the Sea Buckthorn (*Hippophaë rhamnoides* L.) by Dr. C. M. Pearson of Nottingham University; 'Coast erosion and coast protection in Lancashire', by R. K. Gresswell, Liverpool University; 'The uses and limitations of vegetation in shore stabilisation', by C. Kidson, Nature Conservancy; 'The use of certain plants as stabilisers of marine sediments, by G. Cole.



Winterton Ness: A National Nature Reserve. Since the 1953 floods a sea wall has been built along some of the northern part of the Ness. Note the contrast in the dune formation north and south of the village. In the south the houses stand on an old cliff. (*Crown copyright reserved.*)

The little town of Mundesley, also in Norfolk, is naturally worried about erosion. The cliffs on either side of it are receding steadily, and a time is approaching, if it has not already come when erosion will concentrate more and more on Mundesley itself which, as a result of cliff recession on either side, will become a sort of blunt headland on which waves will converge. This is similar to what is happening at Hornsea and Withernsea on the Holderness coast of Yorkshire. But can anything really effective be done to prevent the retreat of cliffs along considerable distances? Millions might be spent on elaborate defence works, and in that sense alone the problem is national. But it is national in a different and bigger sense. The protection of one part of the coast has all too often serious repercussions elsewhere. It is well known, especially on our east and south coasts, that if town A puts out groynes or other defence works, town B, farther down-drift is bound to suffer. Since however, each town or settlement on the coast has grown as a unit, it has looked after its own defence, and so unwittingly has often produced difficulties elsewhere. In fact, there should have been a strong and effective Ministry of Planning from mediaeval times onwards!

The protection of reclaimed marshes and low-lying areas is less likely to produce difficulties. The 1953 storm, however, brought home to all how essential it is to keep banks and walls in proper repair. In several cases, of which Canvey Island was one, the breaching of the walls took place where least expected—where storm effects were minimal, but where the excessively high water caused by the surge overtopped a weak wall and soon caused a serious breach. Extensive research on the building of earth embankments and sea walls is being carried out at the Building Research Station at Watford. Hand in hand with this goes the study of not only the proper types of grass and possibly other plants to grow on earth banks, but also careful observations of their effects if left to grow untended, grazed, or cut so as to form a close sward.

Despite the serious erosion that has taken place along many parts of our coast there are remarkably few measurements of any accuracy of its amount. Some local authorities have taken notes in the past, and more are doing so now, but reliable long-term assessments of loss are rare. Estimates exist of loss

Norfolk Coast near Mundesley: Cliffs of glacial deposits. Erosion is serious both from the sea and locally from land water. (*Crown copyright reserved.*)

on the Holderness[3] coast from Romano-British times, and in parts of East Anglia the amount of erosion over several centuries can be approximated. But no satisfactory overall figure can be given except for quite recent times. On the other hand, gain from the sea often leaves a permanent scale in the form of sea walls and banks now well inland. A journey towards the inner parts of the Wash demonstrates this. Thus, it is comparatively easy to measure the amount of land gained from the sea.

The rate at which changes take place along parts of our coastline is usually very much quicker than that of natural changes that occur in other parts of the land. This is one reason why physiographers and ecologists find the coast so interesting, and why the practical engineer has great scope for his skill. Study of such features as Dungeness, Orford Ness, Blakeney Point, Spurn Head, and many others reveals not only much of interest in the changes taking place at present, but often of the changes that have taken place in the past two, three, or more centuries. These changes may be traced

by careful mapping of the shingle ridges which often form the bulk of these forelands. Sometimes dune growth and movement help in this respect. Thus it is possible in some places not only to trace the physical evolution of a shore form, but also to relate its growth to events in history. The lengthening of Orford Ness [4] in relation to the growth and decay of the port of Orford, and the evolution of Morfa Harlech [5] in relation to the building and use of Harlech Castle are two well known instances. In Scotland the destruction by wind-blown sand of the Culbin [6] estate has been studied in some detail. Sometimes the correlation extends over a longer period, although perhaps in rather a different way, e.g. the sand storm which led to the desertion of Skara Brae in Orkney [7] and the careful excavations which have been made at Jarlshof [8] in Shetland, which show that successive horizons of civilisation and the buryings by sand, cover a period of about 3000 years, during which the site has been almost continuously inhabited. This inter-relation of the coastline with history and pre-history is particularly well demonstrated in many other places, including the growth of deltas in the Mediterranean and Persian Gulf, the decay of former ports, and in the Mississippi delta region by the relation of Indian middens both to delta growth and to sea-level.[9]

Fleethaven: Saltmarshes and reclaiming ground. (*Crown copyright reserved.*)

But whilst these sorts of changes have been taking place, it is likely that, in many places, especially around the North Sea and the Atlantic coasts of Europe, changes in the relative level of land and water have also been taking place. The position of the menhirs on parts of the coast of Brittany, and the submerged walls of the Isles of Scilly [10] illustrate this to any visitor. The evidence is just as convincing elsewhere, although it may be hidden by saltmarsh as in Essex, where the Lynnesse horizon is found a foot or so beneath the marsh surface. That this movement is still in progress is made abundantly clear by a careful analysis of tide gauges in many countries. Eastern England and the Low Countries are sinking: the rate varies both in place and time, but a maximum at the present time is of the order of 8–12 in. a century. The gradual raising of the banks along the lower Thames and the position, relative to present tidal levels, of the Roman occupation surface in and near London prove a change of level of some 15 ft. since Romano-British times.[11] On the other hand, much of the north Baltic area, and many parts of Scotland (e.g. Aberdeen–Dundee) are rising.[12] These changes are traceable to isostatic readjustments of the land surface following its recovery from the melting of the Quaternary ice caps, and also to—at the present time—a slight eustatic rise of sea-level, correlated with the melting of glaciers and ice caps. That these movements have an important economic aspect is abundantly clear if, over a long period, the necessary heightening of sea-walls is considered. A more serious aspect is the relation of dock sills to tidal levels in the Thames, and the prospect of a Thames barrage.

Immediately, however, the point to emphasise is the constant change along a coastline. Fluctuations of level in the past manifest themselves in the occurrence of submerged forests and raised beaches, and of settlement horizons now below sea-level. In the fens, for example, Tardenoisian, Neolithic 'A' (Windmill Hill), and Early Bronze Age levels occur and point to a continuous downward movement of the land. Accompanying these changes of level, and the growth of spits and beaches, there has also often been a more or less continuous change in the vegetation of marshes, fens, and deltas. Swinnerton[13] showed how at Ingoldmells on the coast of Lincolnshire, subsidence of a Romano-British site could be correlated

Dunstanburgh: The Whin Sill, dipping seawards, and the coast from Dunstanburgh Castle to Craster. (*Crown Copyright reserved.*)

with the remains of different layers of saltmarsh plants preserved in the deposits. A visit to any marshland coast today shows, usually with great clarity, that the plants are arranged on the marshes according to the nature of the substrate, wet or firm mud, sandy mud, etc., and also according to the number of times a year or a month they are inundated by the tide. Since the tide brings in with it a great deal of silt which is deposited on the marshes and other sheltered places, their level is constantly rising. But if the coast is moving vertically relative to sea-level, as a result of isostatic and/or eustatic movements, it is of great interest to all students of coastal morphology to consider these movements in relation to the upward growth of marshes. If the upward rate of marsh growth equals or slightly exceeds that of rise of sea-level relative to the land then the marshes will hold their own. On the other hand a marsh that cannot compete in this way will soon be lost, partly by drowning, partly by erosion.

Purely ecological studies are most rewarding. A marshland area is often partly enclosed by, or adjacent to, ridges of shingle and also to sand dunes. Both shingle and dunes are probably mobile, and the one can be pushed and the other blown or washed over the marshes. Hence, varying intermixtures of deposits occur. Each habitat—dune, drift-line, shingle, marsh—has its own flora, and that flora changes with the development of the features on which it grows. As marsh grows higher, so do plants which can stand less submergence gradually replace those, such as *Salicornia*, which tolerates daily submergence. The dune flora changes with the gradual transition from yellow to gray dune and is, in fact, largely responsible for this change. The shingle flora may be subject to interesting changes, especially in those parts where wave action is still effective.

It is then, this constant change that is taking place on the coast that makes it such an interesting place for scientific work. But so far we have considered only the visible parts of the shore. We must now turn to the outer beaches, and pursue our studies partly out to sea and below low tide level. The two dominant factors that concern us are waves and tides, including tidal currents. Wave action is of supreme importance. Waves, approaching the beaches approximately at right angles build up a beach in ordinary weather, but comb it down in storms. Waves which approach obliquely are the causes of beach drifting, and of

Great Yarmouth: The deflection of the River Yar, and the effect of Yarmouth Harbour on the coast farther south (now protected by a wall). (*Crown copyright reserved.*)

the removal of great amounts of material along an open coast. In storms these waves also comb down the beach, and may remove it completely. In the surge of 1953 long stretches of the Lincolnshire coast, where previously a good sandy beach existed, were so scoured that the underlying boulder clay was exposed for some considerable time before normal conditions gradually restored the beach.[14] Wave action is also responsible for direct erosion of cliffs, the more so if the waves are armed with sand and stones. On soft cliffs the rate of erosion may be rapid, and is often greatly helped by the outward draining of land water. Direct wave action can have, in time, a considerable effect even on a hard rock-bound coast as a result of its causing the alternate compression and expansion of air in crannies and joints of the rock.

A study of wave action on a particular stretch of shore is of vital importance, and it is in this connection that tank experiments in laboratories are of help. A visit to the Hydraulics Research Department at Wallingford may be most revealing in this respect. Not only is the action of waves on beaches examined from a theoretical point of view, but more often than not there will be a model in use of some part of the coast of Britain, or other land, built to investigate the effect of wave action upon it. A model cannot replace all the phenomena of nature, but it is possible to analyse various single and combined effects, and also to introduce tidal changes of level. By experimenting with small groynes, sea-walls, piers, or harbour works it is nearly always possible to obtain a clear direction of what to do on the actual coast. In this way many thousands of pounds can be, and are, saved since the model indicates what measures should be taken. Similarly, if tidal currents are suspected of producing serious changes as a result of the removal of finer material from one place to another, they, too, can be simulated.[15]

Models may also help in understanding what happens below sea-level. It is easy to follow in a glass-sided trough the under water effect of waves. In nature this is much more difficult, but partly as a result of observations made in the laboratory, and partly as a result of new methods of enquiry – radioactive tracers, and aqualung divers—we are now in a far better position to enquire into the all important question of what happens off shore.

Tracer methods have been used in this and other countries to investigate the movement of ordinary beach material, or of fine sediment that can be moved by tidal and other currents in rivers.[16] It is an accurate means of establishing movement, but it is not easy to drag the detector over every piece of the bottom even over a small part of the sea floor. However, if stones or sand after being dumped, are moved by waves or tidal streams, it is usually possible to detect the general direction, or directions, of movement. If observations with fluorescent tracers are made on a beach the problem is easier. Whether the material used is silt, sand, or shingle, it is an invaluable means of research, both for tracing the nature of movement in general, and also for the investigation of a silting problem in a particular harbour or river. Since it is now possible to use tracers which are not injurious to health, the process is likely to be extended. Without this means it is almost impossible to obtain any proper assessment, even qualitatively, of sand movement on or offshore. It is perhaps easier to trace pebbles provided they can be adequately marked. The ordinary beach pebbles of the locality under investigation are best for the purpose and the movement of 2-in. pebbles has been traced shoreward in water 16–25 ft. deep affected by waves about 3 ft. high.[17]

It will probably not be long before aqualung methods are more widely employed. They are already practised in California,[18] and an experiment is projected for the Norfolk coast in 1960. Divers can now observe with comparative ease the movements of material on the sea-floor. Naturally conditions vary greatly, and more difficulty is likely to exist, for example, on our east coast where the sand and fine sediment may be stirred up by a storm, and so give the effect of a dense 'fog', than in the calm waters of a coral lagoon. Nevertheless, this method may well be more practicable than a radioactive tracer method, and indeed could well be used in conjunction with it. Its practical application is obvious, but its wider scientific significance may be far greater.[19] Too many of our studies of the land finish abruptly at low water mark. A knowledge of the adjacent sea floor is often just as important—possibly more so—if we are to reach proper conclusions. We need far more information about the zone immediately adjacent to the coast, both from the point of view of its configuration, and of the movement of sediment over it. We also need to know more of the ecology of the sea floor. Although this is a subject mainly distinct from the problems dealt with in this paper, it is one that needs further study. Is it possible to plant in appropriate places seaweeds such as kelp, which in some parts of the world has a noticeably calming effect upon waves passing over great beds of it?

A more immediate problem is to determine details of the movements of stones, sand, and silt on the sea floor both parallel to, and directly towards the coast. There are some parts of the coast where it is very difficult to assert, or even to assume, that shingle travels laterally to feed and maintain beaches. In such places it seems more likely that it comes from offshore, and it is essential to prove or disprove this. An experiment made in 1956 with radioactive shingle tracers suggested that Scolt Head Island might be fed in this way.[17] Aqualung observations should go far to prove it one way or the other. In any event it is important to know better than we do just what the bottom is like offshore; does it provide, for example, a probable source of material to feed the beach? Submersible scrapers have already been used experimentally to take material from the sea floor to replenish the beach, and this method is likely to be extended. The maintenance of a good beach is vital in shore protection work. Groynes are built to maintain it, and if it is present, the waves can spend their energy upon it, and erosion is reduced to a minimum. It may well happen that severe storms may remove the beach, but under normal circumstances it will return. If, however, the drift of beach material is interfered with by groynes, harbour works, or other impediments it may take a long time to replenish a beach, and erosion may have the opportunity to cause serious damage. Thus artificial means of building beaches are sought, and practised especially in America.

Where, for example, a river or harbour mouth intercepts the travel of beach material, the removal of sand by suction pumps from the up-drift side, and its carriage through pipes to the downstream side is not uncommon. The Dutch are also familiar with this process, and J. B. Schijf[20] advocates strongly a shift 'in the old philosophy of protection by groynes and sea walls to a new philosophy of protection by sand fill'. Schijf's paper is provocative and of much interest to all concerned in coastal studies, although it may perhaps appeal most strongly to engineers. He points out how greatly interest in, and study of, the coast has increased in nearly all maritime countries in the last decade or so. This interest is also evidenced by the International Unions of Geography, and of Geodesy and Geophysics. The first already has a commission on coastal sedimentation, and may soon widen its terms of reference. The second has proposed a commission on the dynamics of coastal waters and coastal processes. The Russians, led largely by Zenkovitch, are working extensively in this field, and it is well known that coastal studies of many kinds are encouraged by Government and other institutions in America—mention need only be made of the Beach Erosion Board, The Coastal Studies Institute of Baton Rouge, and the wide range of work in this field associated with the Scripps Institute of Oceanography at La Jolla. A glance through the report of the I.G.U. Commission on Coastal Sedimentation presented at the Rio de Janeiro Congress in 1956 will show how wide and extensive is this interest in coastal studies. In this country the Hydraulics Research Board, the Nature Conservancy, and departments of geography and botany in several universities are interested in practical and research problems. The papers published by the Institution

of Civil Engineers and other bodies concerned largely with sea-defences show not only the great practical interest of the problem, but also how much the engineer links, or could link, his studies with others who are interested in coastal problems from a different point of view.

In considering the ownership of the coast, it is convenient to distinguish between the parts usually covered by the tide, and those above that level. In some places a private person or a public body may own both the 'dry' and 'wet' parts of the coast. The Crown Estate Commissioners own about 50 per cent of the foreshore, defined more easily in words than on the ground, as that part between mean high water and mean low water or ordinary tides. In Cornwall that part of the foreshore owned by the Duchy extends from mean high water of ordinary tides down to the level of low water spring tides. In Scotland the limits are mean high water springs and mean low water springs.

In this country there are certain bodies which hold considerable areas of great beauty, or of scientific interest, along the coast. The work of the National Trust is noteworthy in this respect, and whenever possible any holding it possesses on the coast is one having some depth so that both the setting and the coastline are preserved. The Nature Conservancy is directly responsible for several miles of coast, and is indirectly responsible for many more as a result of their being designated areas of special scientific interest.* The National Parks Commission has designated many miles of coastline as national parks, or areas of outstanding beauty, and may add to this amount. There are also many local nature reserves, looked after and maintained by county councils or societies; Gibraltar Point at the mouth of the Wash is an instance. Many private owners are most meticulously guarding and preserving many miles of unspoiled coast. But what will happen when many estates bordering on the coast change hands or suffer the effects of death duties? The threat of spoliation is severe and increasing. The whole country has recently been made aware of the problem by the publicity given to the enquiry concerning the nuclear power station to be built on Dungeness. But power stations of this sort are but an incident. Nearly the whole coast from the Thames to beyond Bournemouth is either built up, used for bungalows, or in some way or another disfigured. Miles of coast in the north, both on the west and east sides of England, are ruined by industrial development. Industry is also spreading in South Wales and elsewhere. Seaside towns are expanding, too often along the coast. Anyone who knows parts of the coast will be able to multiply examples. It is absolutely essential, however, to visualise our coasts as a whole and see how much has already gone, and where the main threats are. People will rightly wish to visit the coast in increasing numbers. Is there any overall (or even local) planning for extensive car parks, for proper camping and other tourist facilities? It cannot be emphasised too strongly that although certain selected places have been chosen for scientific study, *any* piece of unspoiled coast has a great scientific value as well as an aesthetic one, and every effort should be made to preserve it in its natural state.

Dorset Coast: Alternate headlands and bays. The beaches are popular, and access and parking offer problems. (*Crown copyright reserved.*)

The increased interest in the coast from the engineering and scientific points of view must be

* In all, the Nature Conservancy is interested in about 430 miles of coastline in England and Wales.

matched from the aesthetic and planning aspects. Even since the war many miles of beautiful coast have been lost. The nation possesses a magnificent heritage in its coast which, it may be asserted without fear of contradiction, is more varied than that of any comparable length anywhere else in the world. A recent measurement of the length of the coast of England and Wales was 2750 miles. But it is a very narrow belt and for that reason all too easily spoiled. Recent informal discussions under the aegis of the Nature Conservancy have considered the problem.

The coast is a most vulnerable belt, and this country is not alone in deploring the misuse of much of it and, what is more frightening, the ever increasing demand for more and more of the natural unspoiled coast. The United States, through their National Park Service have recently published two interesting brochures showing many of the parts held in perpetuity as parks, and a smaller book drawing attention to the severe depredations made on the remainder.[21]

If those parts of our own coast which are still unspoiled are to be preserved, action must be taken both effectively and at once.

North Devon Coast at Combe Martin: A coast of resistant rocks; hog's back cliffs in background. The popular valley settlement attracts tourists and presents difficulties on the preservation of amenities. (*Crown copyright reserved.*)

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TEACHING SCIENCE TO JUNIORS BY THE DISCOVERY METHOD

By N. F. NEWBURY *Director of Education, St. Helens*

H. E. Armstrong and Heurism

The infant learns by observing and experimenting and the growth of intelligence at this age is altogether marvellous: we have yet to learn what effect the maintenance of such an attitude throughout the school period will have on the individual.

Boys and girls generally must not be confined to desk studies: they must also learn a good deal about things: they must be taught to do things. (We must) inculcate habits of observing accurately, of experimenting exactly, of observing and experimenting with a closely defined and logical purpose . . . individual eyes and hands must be practised accurately and persistently from the very earliest period in the school career.

Commence experimental studies at the very earliest possible moment, so that children from the outset may learn to acquire knowledge by their own efforts . . . so that experimenting and observing become habits.

First, as to appliances. There is a very wrong idea abroad that very special and expensive accommodation must be provided. This is not the case. There must, however, be space in which the work can be done; there must be a workshop . . . and much should be done with home-made apparatus. Utilise ordinary articles—medicine bottles, pickle bottles, jam-pots, saucepans, etc. Construct apparatus in the workshop. Infinite injury is done at the present day, invaluable opportunities of imparting training are lost by providing everything ready made.

Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer—methods which involve their finding out instead of being merely told about things. It should not be necessary to justify such a position in education.

These quotations from speeches of H. E. Armstrong more than sixty years ago summarise his plea for the teaching of scientific method as a way of solving problems. The main points he makes, suitably modified, are still applicable today.

Primary Schools Today

My essential plea is that Physical Science, in its broadest terms, rather than Nature Study alone, should be introduced into the school curriculum at the ages of say ten and eleven in both Primary and Preparatory Schools, to be accompanied by improved conditions in our Primary Schools and, where necessary, in our Preparatory Schools. There is no justification for the present pattern of decreasing the average numbers in a class as the age increases—40 in a Primary Class (up to 11 years of age), 30 in a Secondary Class (ages 11–16), 15 or so in a Sixth Form (ages 16–19), and 10 or so in an advanced Class in a Technical College (ages 19 upwards). The basic teaching in any subject is certainly the most important. A fraction of the cost at present spent on Technical Education would surely be better used in supplying, for example, each Junior School with at least one workshop, with water, gas and storage facilities, for the joint use of light Crafts, Art and Science. In the meantime, many enthusiastic teachers succeed in teaching Science. Trees are planted in school grounds; ponds, gardens, aquaria and vivaria are maintained; apparatus is improvised and almost unsurmountable difficulties overcome.

What is this Junior Science?

It is certainly not a wholesale transfer of the typical formal Science often taught in Secondary Modern Schools, nor snippets of Science remembered from our Grammar or Public School days. Neither should Junior Science be taught under headings—Sound, Heat, Light, Chemistry, etc.

Rather, it should embrace broad fields of interest from all branches of Science, including Nature Study, with no artificial boundaries. If necessary,

trespass should occur into regions of so-called Geography, History, Astronomy and Geology. It is important that the field of interest should essentially be one within the understanding of the child—arising naturally from his own environment and his own needs. Most important, however, the child should feel there is a problem to solve, he should not be told the answer but should be taught the method of discovery, of personal experience, an attitude of doing, observing, investigating and recording, leading later to observing, measuring, experimenting, thinking and reasoning. In other words, the method is more important than the content.

The content is not, however, unimportant in Science since it includes questions a well-trained and intelligent child is continually framing: Why do things fall over? How is a compass made? Why do some things float? How does my electric torch work? Why have I two eyes? How can I move heavy things? Why doesn't a bird in flight drop to the ground? What is wind? How does a catapult work? How many legs has a millipede? What is a rainbow? Why does a mirror reflect the sunshine? Why are there wheels on a car? How can I find my way at night or in a forest? How can I make my model aeroplane fly better? Why does a balloon in front of a fire burst? What are lightning and thunder?

So many of these questions asked by children are concerned with why, how, what, when and where—questions involving doing, taking to pieces, putting together, puzzling out, making, collecting, classifying—all natural activities of children of this age. Girls are just as active, enthusiastic and successful as boys between the ages of eight and thirteen. Later, girls in particular seem to lose this zest for experimenting. In any case, junior children rightly taught will be much better prepared to approach the Secondary stage.

5000 Questions linked with Science asked by Children, aged 11

TABLE 1

UNDER GENERAL HEADINGS

1186	Natural Phenomena
753	Human Body
718	How Things Work
393	Animals other than Human Beings
333	How Things are Made
273	Plants
260	Air and Space
251	Electricity
134	Heat and Fire
130	Floating
608	Miscellaneous

TABLE 2

QUESTIONS WHICH WERE MOST FREQUENTLY ASKED

1. How does an aeroplane fly?
2. What is electricity and how is it made?
3. What are the uses of hair on the body?
4. How do the eyes work and why do we wear spectacles?
5. How does a television set work?
6. How does a motor-car engine work?
7. How does a watch or clock work?
8. What is air and what is it made of?
9. What is lightning and how is it made?
10. How does the earth revolve?
11. How is rain made?
12. How is thunder made?

Selection of Material and Methods to be used

The criteria for deciding which fields of interest should be selected are:

(1) Science should basically be centred on the hobbies and interests of the child of today. Much has still to be learnt about our children's permanent and real interests at different ages and their abilities to learn and to reason. Many educationalists doubt if our more able children are sufficiently stretched.

(2) The child's love of finding out and doing things for himself should be utilised. The experiences must be genuine, vital and undergone personally by the child.

(3) The need to reduce the content of the Nature Study syllabus and particularly to alter the method of approach should be considered. In past years, Nature Study has often been taught as a passive reading or drawing lesson. Material is often difficult to obtain in urban areas, children have often little urge to study the subject and the emotional attitude has been over-emphasised.

(4) A definite link should be made with the child's daily life and his environment—his body, safety, running of his home. He should be trained to protect and love the countryside, to refrain from collecting and destroying rare plants and animals and to conserve coal-gas, water and electricity and to live a healthy and full life.

(5) The material selected should be suitable for problem-solving and the titles should be stimulating and challenging. No longer should titles be of the type: 'To prove that a gas expands on heating'; 'To show that a magnet attracts iron'. Instead, titles should be of the type: 'To find out how much snow is required to form one inch depth of rain'; 'How to make a compass'; 'How does an aeroplane work?'

(6) Opportunities, however, simple, should be provided to develop the right attitudes of the future citizen in a democratic state—open-mindedness, challenging the claims of advertisements and what appears in print, and doubting superstition.

The chief difficulties are first, to translate the specialised terms and explanations of Science into precise language which can be understood by juniors. It is a challenge to an enthusiastic teacher to explain accurately but in words which can be readily understood by an eleven-year-old girl or boy why, for example, grass is green or how a telephone works. Secondly, to select fields of interest suitable for teaching purposes of real intrinsic rather than transient value. In other words although topical and incidental experience are valuable, each year's course should be planned in detail. Flexibility in the use of the time-table is accepted in Junior Schools today. Much of the teaching with lower juniors, however, should be incidental and linked with the Investigation Table.

A Typical Approach

A typical approach in snowy weather would be to discuss with members of the class the relevant questions they raise on snow and ice—the kind of experiment to be done and apparatus and material required; the problems to be solved. The next day and on succeeding days, following preliminary questions, groups of children then examine snow flakes and snow crystals with a magnifying glass on a dark background, they feel snow and compress it to make an artificial iceberg, put it in water, leave a tin full of snow on a hot radiator to find out how much water forms, float snow and ice (including cubes from a refrigerator) in water, leave corked and uncorked bottles and jars full of water in the open in freezing conditions and carry out other experiments that can be done on a cold and snowy day. After seeing and doing these experiments, the children discuss their findings and make brief statements in their note-books. There are obvious links with the child's environment—snow-balling, skating, snow-men, damage to trees, help to the farmer, breaking up of the roadway and playground surface, frozen pipes, thermometers. This area of interest illustrates the value of a series of smaller experiences for this age group rather than one long, tedious experiment.

Simple Apparatus

The use of simple, commonly occurring apparatus and material is advisable. Use whatever is supplied by nature—air, water, soil, etc.— and what occurs or is made in the district—clay, glass, coal, fossils, etc. Use rulers, for example, and chair backs as balances; medicine bottles, jam-jars, buckets, wash bowls, tins, plasticine, milk straws, candles, wire and balloons. If the child designs special apparatus and cannot make it himself, get a father or boys from the nearby Secondary School to make it. The art of invention and improvisation must be developed. Boys and girls seem to inherit their ancestors' ability to design, to take on responsibility, to work intelligently as individuals, or in small groups. Science presents unusual facilities for such communal working.

Teachers and lecturers in Education ought now to be working on the relative merits of the demonstration, group and individual approach to Science; the right methods of presentation; how to use to the full the capabilities of the clever Primary child as well as the less able. Many more boys and girls ought so to be trained in our Grammar Schools and in our Training Colleges. Our future success as a nation essentially depends on providing sufficient men and women able to teach Science and Mathematics effectively so as to produce not only future Science specialists, but above all, good citizens, with some knowledge of the principles and methods of Science.

Suitable Science cards and text-books stressing the discovery method, reference books and readers for all ages dealing with the lives and methods of great inventors and scientists must be published.

Another Field of Interest

All children, however, should in this scientific age gain appropriate experiences through Science

activities—often in an attempt to answer many of the questions which the inquiring child of today asks his elders. Some of the topics are not new—boys have for many years reflected the sun into each other's eyes, used a lens to light a fire, pulled an electric torch to pieces, attracted pieces of cotton or paper with a rubbed fountain pen, exploded a balloon, sausage or chestnut on or near a hot fire, dropped stones into a smooth pond, seen the colours of the rainbow in glass lustres, played with magnets, balanced poles, found out how to move a tree trunk or a large stone, floated boats, made gliders, arranged competitions on the longest time to hold one's breath, pulled their mechanical toys to pieces—all excellent beginnings to a Junior Science lesson, but rarely used. Changing social conditions and major developments have accentuated the desire of young children to discover answers to questions involving scientific knowledge and it is our duty to find out more about these basic interests and these new interests and use them to the advantage of Science teaching.

Details of specific lessons might be given. A class of forty-two were told three days before the lesson (and reminded again on the morning) to bring needles and magnets from home, along with pieces of other metals or small metal objects. It was a surprise to the author to find that thirty-three magnets were brought but not a single bar magnet! First the children were asked if a magnet would attract a penny or a sixpence and, by show of hands, their opinions were recorded on the board. They then found out whether or not their answers were correct. Next they sorted out the things which were and were not attracted by their magnets and if the magnets would act through paper, glass, etc. The children then stopped experimenting and by questioning, were led to explain how a needle could be made into a magnet. This was done. The next problem was to discuss how to so suspend or support the needle that it could turn in any direction. This was given as a class problem and the best proposal to float it on a piece of cork was carried out. The children then stood, and with their arms outstretched, showed the direction in which their magnets pointed. Most of them realised now that the magnet pointed North and South and that they had made a compass. For homework, discussion centred on the different ways to suspend or hang a needle or piece of steel and the children were then left to devise alternative methods of support and to modify the compass as they wished. In the next lesson, the different designs for a compass suggested by different members of the class were exhibited. One member of class pointed out that there were two North Poles—a geographical and a magnetic pole!! The lesson was continued by discussion on the use of compasses and types of compasses known. Finally, a discussion and demonstration for revision purposes on how to make a compass from a ping-pong ball, knitting needle and any other material completed the lessons. It should be noted that the orthodox approach of dealing with such unreal terms as 'To show that like poles repel and unlike poles attract' were omitted in class. Rather the spirit of discovery, observation, improvisation, wonder and utility were stressed. It is true, however, that brighter children floating more than one magnetised needle on the surface of water discovered such relationships themselves, but they expressed their results in different ways.

Recommendations

As in the past, the British Association ought to take a leading part in stimulating the teaching of Science in schools and to consider if they could take action on the questions raised below:

(1) The need for maximum sized classes of 30 in Primary Schools, the provision of more teachers qualified in Science, particularly women, and of better accommodation, should be major priorities of the Ministry of Education.

(2) Firms should be approached to extend the provision of suitable pamphlets, charts, samples, working models and film strips. Publicity managers of such firms should be in more direct link with practising teachers and the needs of children. There has fortunately been much improvement in this respect and in arranging worth-while visits.

(3) Careful consideration should be given to the question of giving financial help to promote the extension of teaching Science in Junior Schools and Preparatory Schools. Such investment would be of considerable value to the nation. If, for example, the B.B.C., I.T.V., and newspapers forgot for a period about the so-called eleven-plus examination and gave publicity to constructive proposals and discussions amplifying the points raised in this

short paper and supplied a regular and reliable service on Science topics, infinitely more value to both individuals and the community would result.

There are many positive proposals one could make—teams of experienced men and women could visit groups of teachers throughout the country and give practical advice on Science teaching in Junior Schools. Models and material could be made more readily available. Such a scheme could be officially sponsored and could stimulate interest and research in Training Colleges and in Institutes and Schools of Education. The Ministry of Education could be pressed to publish a series of pamphlets on Science teaching at all stages.

The B.B.C. and I.T.V. might consider the advisability of providing courses on the teaching of Science in addition to programmes for the children themselves.

Further, the British Association could appoint enthusiastic and experienced scientists and teachers to issue reports and recommendations of practical value on all aspects of Science teaching. This would involve the British Association in pioneer work—simply history repeating itself.

Finally, I am convinced that efficient and experienced teachers in our Junior Schools, who feel the vital need to teach Science, rather than the specialist, will solve these difficult problem — particularly if they adopt the successful and active methods used in the best of our Infant Schools. May the maximum amount of encouragement and financial aid be made available to our teachers!!!

A POLICY FOR SCIENCE

In his Presidential Address to the American Association for the Advancement of Science, Chicago, December, 1959, Dr. Wallace R. Brode asks whether science has changed in relative importance over the years since the founding of the United States. He notes that in the 1930's the Federal Government was supporting only about 15 per cent of the nation's basic research which was almost exclusively in its own laboratories. Today, the Federal Government is supporting about 85 per cent of the nation's basic research, of which still only about 15 per cent is in its own laboratories. 'This means that our scientific research programme is directed and guided by governmental defense agencies.'

Dr. Brode concludes 'that a national science policy is needed for a wise and rational distribution of scientific activities, so that space, defense, education, atomic energy, oceanography, and medical research are not bidding against each other for limited available support. The growing demand for scientists in the face of a limited supply of scientists, materials, funds, and facilities requires major policy decisions as to the distribution of resources.'

He believes also, however, 'that scientists must realise that there should be a relative priority assigned to areas of science and that there should also be recognition that scientific programmes do not all have priorities that override economic, political, educational, and social developments.'

Dr. Brode concludes his Address—which contains much that is of interest to us in our own debate on the rôle of the Government in Science—by saying 'that the government does have a responsibility to continue to support science, just as it has a responsibility for health, agriculture, and defense. There must, however, be some instrumentality with a considerable degree of control, which can decide when to support, when to taper off, or when to terminate various research programmes—and such responsibility must eventually centre in a coordinating establishment such as a Department of Science.'

TIME TO REACT

By D. E. BROADBENT *Director, Applied Psychology Research Unit, M.R.C. Cambridge*

It takes you a fair amount of time to deal a pack of cards in the ordinary fashion; but it would take you even longer if you were to look at each card and make sure that you dealt yourself all the hearts, your partner all the diamonds, one of your opponents the clubs and the other the spades. Yet the movements made by your hands would be no longer or more burdensome in the latter case. The extra time is accounted for by the delay between the image of each card striking your eye and the beginning of the corresponding movement. During that delay a decision is taken and a choice made, and the movement which emerges is the result of that choice.

Now these decisions are no doubt much simpler than many which are met in everyday life, but they are nevertheless extremely marvellous processes. There is a considerable mystery in the daily miracle that when we ask somebody for a pint of bitter he usually gives us what we ask for and not something else. Our wonder at the reliability of human behaviour gets dulled with familiarity; but it should not be so, and we ought always to ask ourselves how these regularly successful choices are achieved. The study of reaction times is one way of asking this question.

Quite apart from this theoretical interest, reaction times are of great practical importance. The Post Office, for example, handles nine thousand million letters a year. If a psychologist can reduce the time taken to sort each letter by only one-thousandth of a second, he has saved the equivalent of his own working hours for as long as letters continue to be sorted by human beings: and that means the foreseeable future. A large number of countries are however, building machines in which the sorter is shown each letter through a window and merely presses a button for the particular town to which the letter has to go. The machine then takes the letter away and puts it in the right sack. Now most of these machines operate at a speed set by the machine itself: a letter appears at set intervals, and the man has to keep up with the flow of letters. In the British machine however, each letter is delivered when the sorter presses the button for the previous one—so the rate of work is set by the man. There are a number of psychological reasons for thinking that this is a preferable system, but for our purposes one is the most interesting. If a man is sorting letters in a given town, say York, he is not equally likely to meet letters to all the possible places in England. There will be more letters to London than there will be to Littlehampton, and so he will have to make one reaction more often than the other. If then his reaction time is affected by the probability of a particular reaction, by the frequency with which it is demanded, he will not be able to deal with a letter to Littlehampton in the same time that he will cope with one to London. When the speed of work is set by a machine, it will be necessary either to cut the man dangerously short of time for the slower reaction—or else to make him waste time for the faster one. A machine which lets him work at his own speed allows him to speed up when he can and slow down when he must (Fig. 1).

Now it is in fact true that probability is important in reaction times. If you sort a pack of cards into the four suits, it will take you longer than sorting merely into red and black cards: and it will take you longer still if you separate the court cards from the others within each suit, so that you have eight piles of cards at the end of your sorting. As the number of alternative reactions goes up, and the probability of each goes down, the time taken to react increases. There are some very important exceptions to this rule, which are relevant to the views developed later, but the most important point is not that reaction is slower to improbable signals (which

Fig. 1.—A reaction time experiment in progress. When one of the lamps is illuminated, the subject has to press the appropriate key as fast as possible. The clock above her head indicates the elapsed time between the appearance of the light and the pressure of the key.

isn't even true in every case) but the nature of the relationship when it is true.

The relation between time and probability which one gets is a familiar one to communications engineers, because it applies to radio and telephone circuits as well as to the brain. If one halves the probability of a signal and gets an increase in reaction time of a certain amount, halving the probability again will increase the time by that same amount. This happens to be the way in which the time per message alters in a particular radio or telephone channel as you alter the probabilities of the messages: provided that you are making the best possible use of the channel (Fig. 2).

Any other relationship between time and probability implies that you aren't making the best use of your channel. So from the results of reaction time experiments it looks as though the human brain is deciding as efficiently as it can, given the limitations which as a physical system it must have.

This is very encouraging, particularly to those of us who have occasional doubts about the efficiency of our own brains: but the fact does more than just bolster human self-esteem. As was said earlier, time and probability are related to one another in certain physical systems, by the same function that relates reaction time to stimulus probability. But the systems of which this is true are those in which the consequences of one event take into account all the other events which might have happened, in which in fact one event is not independent of the other possibilities. In many simple physical systems this condition isn't satisfied. For example, consider the time which elapses between the pressing of a key on a piano and the striking of the wire which results from that event. This time depends on the mechanical linkage between the key and the hammer, and the linkage is completely specific to that key. It isn't affected by any of the other keys. It remains the same whether those other keys are in use or not —it's not affected by the probabilities of various notes in the music being played, or anything of that

sort. As a result one can play two notes very rapidly after one another, or even simultaneously, and the piano doesn't misbehave as a result. But then a piano is not like a person. The situation is quite different in the sort of physical system which *is*, in the way we're considering, like a person. In a radio channel, if you try to send a second message at the same time as a first there will be interference between the two. One message isn't independent of the others, and so one can block another in a way that the separate independent keys of a piano cannot. The kind of physical system, for which time increases by a constant amount every time you halve the probability, is a single-channel system. You can get into trouble by trying to put too much information through such a single channel, just as you will have difficulty in pouring a bucket of water away down a wash-basin whose waste-pipe is already blocked by a previous bucketful.

So in those situations where reaction time obeys the mathematics of information theory, it suggests that the brain is acting as a single channel or pipeline, and that any second stimulus coming in, at the same time as or closely after a first, will not receive a very efficient response. That fits in with our everyday ideas about attention and distraction. We do feel that just after one situation has arisen, while we are concentrating on it, we are in no state to cope with something else. Such feelings are very unreliable, but in the last ten years a number of experiments have been performed on the efficiency with which people respond to such rapid sequences of signals, one after another. On the whole these experiments confirm that in suitable situations the second stimulus gives a slower reaction than it would if it came on its own. Dr. Roy Davis of Oxford, for instance, has reported that when you put a man in front of two lights, tell him to press a key with his right hand when one lamp lights and a second key with his left hand when the other does, the reaction times are much affected by the time interval, between the lighting of the lamps. If the second stimulus arrives after the first reaction is over, the second reaction time is normal: but for every tenth of a second that the second stimulus arrives earlier than the first reaction, you have to add a tenth of a second to the reaction time. The second stimulus queues up to be dealt with, waiting until the first is out of the way: just as when you pour two buckets of water into a basin very rapidly one after another, the second bucketful has to wait in the basin until the first has gone down the waste-pipe (Fig. 3).

Unfortunately Davis has also provided another fact which is harder to fit in. Our various senses do not all take the same time to pass messages to the brain. The ear gets its message in quicker than the eye does; and correspondingly the reaction time to a sound is quicker than the reaction to a light. Since this is so, a reaction to sound ought to produce interference with other reactions for less time after the stimulus is delivered. But it doesn't. It interferes for just as long as a visual stimulus does—which means that a sound may interfere with reaction to a later signal even though the response to the sound itself is over and done with. It's as though one poured water into a wash-basin, watched it run away, and then poured in a second bucketful and to one's amazement saw it wait in the basin for a while before flowing down the pipe. Now there are several possible explanations of this, of which one is that the brain might not work by taking in a steady stream of information, but rather by taking in a series of chunks. The idea is that a sample of events is collected by the eyes or ears, formed into a parcel and dealt with by the brain as a unit. If a signal misses its chance of getting into one chunk, it has to wait until the next sample is dealt with by the brain, and that may cause a delay. If we go back to the analogy of pouring buckets of water down a waste-pipe, this new theory corresponds to the idea that we're dealing not with a wash-basin but with a lavatory cistern. As we all know to our cost, once you've pulled the plug the cistern has to fill up before you pull it again. So if two drops of water enter the cistern in rapid succession, one just before you pull the plug and one just after, the second one won't go down the pipe until after a delay.

This kind of theory explains why the delay is just as great whether you use a light or a sound to produce your reaction. If the delay isn't due to the time for which the channel is filled, a stimulus which gives a faster reaction time need not give less interference at all. And besides explaining this difficulty, the theory has other implications. If it were true, one ought not to be very good at telling the order in which things happen, provided they happen close enough together to get into the same sample. If two drops of water go into a lavatory cistern, they won't necessarily go out down the drain in the same

order when you pull the plug. Now it does happen that people are very bad at telling the order in which things happen. It's been known for a long time that you can't judge very well whether a light-flash and a sound are simultaneous or not, but nobody thought much of it because as mentioned earlier, the different senses take different times to pass messages to the brain anyway. But recently there have been some experiments by Mr. Ladefoged of Edinburgh, and by myself in collaboration with him, which show that one is very inaccurate even when two sounds follow one another. For instance, one cannot tell exactly where a click occurs on a tape recording of speech.

These experiments suggest that the brain does not take in sounds strictly in the order of their arrival at the ear. Rather it looks as though all the sounds which arrive within a certain short time are sent through the brain together in a single chunk. But this of course doesn't provide evidence of sampling in the reaction time situation itself. The last experiment to be mentioned, again by Ladefoged and myself, provides such evidence. This is a study of reaction time to spoken words. You could describe it as an attempt to find out whether one listens to each sound in turn in a word of command,

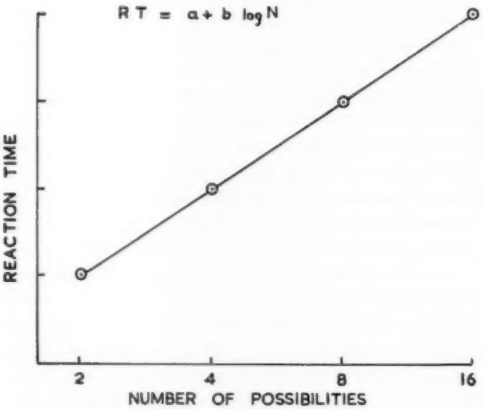


Fig. 2.—The typical relationship between reaction time and the number of alternative signals to which the subject may have to react. Notice that the time increases by an equal amount whenever the number of alternatives is doubled. In some cases, extra alternatives may take very little or no extra time: but when extra time is taken for improbable signals, the relation is of this form.

or whether one hears the word as a whole. The method one uses is to tell the listener in advance that the word is going to be one of a certain small vocabulary: for instance, its going to be either *bid* or *did*. If it is *bid*, he is to do nothing, but if it is *did*, he is to press a button. Now he ought to be able to make up his mind to press the button as soon as he hears the first sound *d* rather than *b*. So one ought to get a normal reaction time from the start of the word to the button being pushed. But suppose the two words are *bid* and *bed*. Then he can't make up his mind whether to press the button until the second sound in the word arrives—the first sound is the same whichever word is spoken. So the reaction time ought to be very long if one measures from the start of the word, and experiment confirms this.

At first one might think this supports the idea that the listener deals with one sound at a time: but actually it isn't so. One merely has to suppose that the listener arranges to close his sample as soon as the crucial information is in. In terms of the lavatory cistern analogy, he pulls the plug when a particular drop of water has reached the cistern. If he can do this just after the beginning of the word, he will get his reaction out sooner. Of course, he will not be able to react to anything else about the word until another sample has been completed—until the cistern has filled up. But in the experiment mentioned, that doesn't matter.

Now suppose that some of the important features of the word are at the beginning, and some in the middle. Suppose, for example, that the listener hears in random order the words *bid*, *did*, and *bed*, all mixed up together, and he is told to press his button only if the word is not *bid*. If he now closes his sample just after the beginning of the word, and if the minimum length of a sample is comparable with the length of the word, he will be very slow indeed at dealing with the information in the middle of the word. So he will probably not adopt that strategy, but rather close his sample after the second sound in the word. Thus he will make moderately rapid responses either to *bed* or to *did*, but there will be no difference between the two words. In addition the time taken for *did* to produce a response will be longer than it was in the simple experiment where *did* and *bid* had to be discriminated. The results of the experiment turn out to support this argument. So we think that this experiment shows the importance of perceptual sampling in reaction time. You

listen to a series of sounds before deciding to act, rather than acting on each sound as it arrives.

To summarise, there are at least two kinds of limit on human decisions to react. There is the effect of the probability of the signal, and there is the effect of our perceptual sampling time which makes our observation of the outer world intermittent. It seems quite likely that as one becomes increasingly practiced at certain jobs the effect of probability becomes relatively less important than that of sampling time, because the latter sets a limit beyond which one cannot speed up work. In a similar way, for instance, a skilled typist is no faster when typing a series of Xs and Ys than she is when typing English, although in the latter case each letter is far less probable. But this takes us on to the research which is now in progress. We cannot finish the story, because its hardly begun.

These results are of practical value. But in addition this kind of research is changing our ideas about the processes which go on inside our heads. We cannot think, as our grandfathers did, of a lot of separate ideas becoming associated in the mind: nor as our fathers did, of a lot of separate connections being built up in the nervous system between our senses and our muscles. The brain is not like a piano keyboard; it is to a great extent a single channel. The phenomena which we usually call attention and distraction correspond to important features of the organisation of the nervous system and are not to be dismissed as accidental freaks of our conscious experience.

This correspondence, between everyday feelings and the results of our rather cold-blooded measurements of time, raises an important point. The whole approach adopted here has been one which uses, for the study of human beings, the techniques of engineers. But people are not radio or telephone channels, and of course all of us who are engaged in this type of research are well aware of the difference. But we study the things we do because we believe that in the end there is only one way to disentangle the frightful hash which most human relationships are in. That way is to observe people by the same methods as those used in other sciences, and so to build up a body of knowledge which is agreed and not dependent on opinion. Many of the

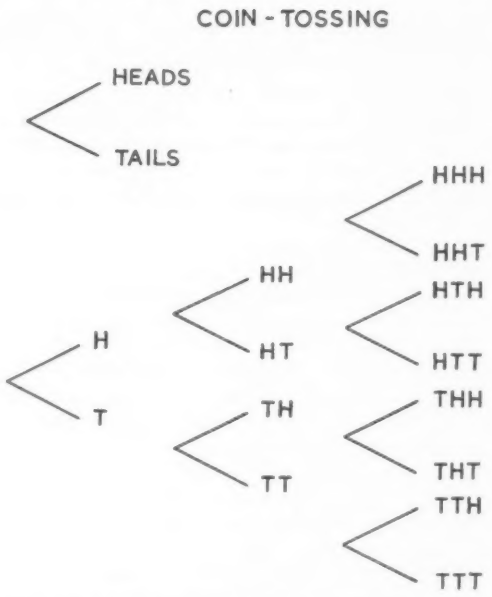


Fig. 3.—The ideal relationship for distinguishing alternative courses of action by tossing a coin. One toss of the coin distinguishes between two alternatives, two tosses between four alternatives, and three tosses between eight alternatives. Thus the coin tosser takes the same extra amount of time to make a decision every time the number of alternatives is doubled. This is the most efficient strategy to adopt, and gives a relationship between time and number of alternatives similar to that in Fig. 2.

disorders of behaviour which we call mental illnesses and crimes and which cause so much suffering seem to involve disorders of attention, or of the estimation of probabilities; people don't notice important things about themselves, or fail to learn the skills involved in living together. So there is nothing unrealistic about hoping to reach the core of personality by studying those topics. But it is bound to be a slow process, and it does mean that we can't tell people today how to stop quarrelling with their family. There isn't any easy answer to human problems, but there will be an answer one day.

CHEMISTRY AND CLOTHING*

By Dr. J. W. BELL and Prof. C. S. WHEWELL *Department of Textile Industries, University of Leeds*

In view of the remarkable scientific developments in recent times, it is perhaps surprising that most garments are still made from textile fabrics. While this may, by some, be regarded as an indication that the average person is extremely conservative in taste, it can more truly be seen as an unsolicited testimonial to the value of textile fabrics as materials for clothing. A great change has, however, occurred in the textile industry—a craft industry has been transformed into a branch of applied science, and modern textile fabrics combine beauty with functionality. They are made from an extremely wide range of raw materials and are improved in appearance, texture and usefulness by a host of chemical and physical treatments.

The greater part of the textile industry has what is known as a horizontal structure, being divided into different sections such as spinning, weaving and finishing. Each utilises entirely different processes and skills, and in the last fifty years there has been added to them another section, viz. that of making the fibrous raw material which previously had been gathered from animals and plants. In spinning and weaving, the chemist has had relatively small influence, and although his skills have been widely utilised in the finishing of fabrics his greatest triumph undoubtedly lies in the synthesis of fibres, for this has made possible the construction of a variety of new fabrics having wide utility and appeal.

Modern supplements to the natural fibres can conveniently be divided into two categories: firstly, the regenerated fibres in which a naturally occurring product is extruded (with or without major chemical modification) in fibrous form and, secondly, wholly synthetic fibres whose long-chain molecules are built up from compounds of low molecular weight. The new finishes, however, are more difficult to classify on a fibre basis as many can be applied to widely different types of material. They serve not only to enhance desirable and eliminate undesirable characteristics but also to confer on fabrics entirely new properties.

The real cost of a fabric depends not only on its purchase price but on the frequency with which it needs to be replaced, and in the old days excellent durability could only be, and often was, obtained by purely mechanical methods such as having a very robust and heavy structure. Nowadays improved wearing properties may be obtained without increasing the weight by using very strong fibres either by themselves or in admixture with conventional fibres. The new synthetic fibres nylon (polyamide) and Terylene (polyester) are outstanding in this respect, and both owe their discovery to fundamental work carried out during the 1920's. During these years it was established that natural fibres and rubbers were built up from linear polymeric macromolecules of very high molecular weight. Attempts were naturally made to make such polymers from low molecular weight starting materials, and the first practical success was obtained by Carothers, culminating by 1935 in the spinning of polyhexamethylene adipamide now known as

* Based on the following four papers presented at the 1959 Meeting of the British Association for the Advancement of Science:

'Physical Aspects of Clothing for Comfort', by W. H. Rees (British Cotton Industry Research Association).

'The Chemical Treatment of Apparel Fabrics', by C. S. Whewell (Professor of Textile Technology, The University of Leeds).

'Recent Advances in the Application of Cellulosic Man-Made Fibres and Clothing', by H. A. Thomas (Messrs. Courtaulds Ltd.).

'The Use of Synthetic Hydrophobic Fibres in Clothing', by A. B. Thompson (Imperial Chemical Industries Ltd., Fibres Division).

nylon 66. At that time the polyesters did not appear suitable, apparently having insufficiently high melting points. In 1941, however, the polyester polyethylene terephthalate was prepared by Whinfield and proved to have an adequately high melting point; this appears to derive from the inherent stiffness of the aromatic paraphenylene links rather than from specific intermolecular forces like the hydrogen bonds in the polyamides. However, despite the brilliance of these inventions and the ingenuity demonstrated in solving the problems in chemical engineering associated with developing large scale processes for converting the polymers into filaments with highly oriented fibrous structures, much still remains to be done to explain the physical properties of the resulting fibres.

The Young's moduli of most crystalline, glassy and metallic solids lie between 10^{11} and 5×10^{12} dynes/sq. cm., falling slightly with rising temperature, the corresponding elastic extensibilities being approximately 1 per cent. This phenomenon is easily explained in terms of internal energy changes. At the other extreme, rubber has a modulus below 10^{7} dynes/sq. cm., rising with increasing temperature and having a corresponding extensibility of about 1000 per cent. This behaviour could not be interpreted until the concept of long chain molecules was developed in the twenties, when it became clear that elasticity was due to configurational entropy changes rather than to a change in internal energy; bond rotations rather than bond deformations are involved. Between these extremes there is an intermediate range of materials, such as wool, silk, cotton and plastics which are more extensible than metals, etc., but have higher moduli than rubbers. They are in an intermediate state of limited molecular flexibility and both energy and entropy factors are important in their deformation. The transition range is wider than with rubbers; for example, both nylon and Terylene approach glassy properties below $-200°$ C. and rubbery properties above $+200°$ C. Measurement of the hysteresis energy loss shows that over this range the loss is often resolvable into more than one peak, and tentative theories have been advanced in an attempt to interpret these peaks in terms of different modes of molecular flexibility. For example, the lowest peak in the hysteresis energy loss of nylon is supposed to be due to rotations in the covalent carbon–carbon bonds of the aliphatic chain sections; this is followed by a middle peak caused by rotations in either the carbon–carbon or carbon–nitrogen bonds of those amide groups which are unrestricted by hydrogen bonding with neighbours; and finally, the upper peak is attributed to the onset of rotations which only become possible when inter-chain hydrogen bonds can be broken. The introduction of this type of theory is helpful in suggesting that once a fibre is in an intermediate state of flexibility it is probable that a condition of more rubber-like flexibility can also be reached. In natural fibres heat alone cannot induce it to anything like the same extent, the plasticising action of moisture being necessary, but with nylon and Terylene an increased temperature is all that is needed to provide the correct conditions for processes such as setting, pleating and ironing. The presence of water should not have an overriding effect on these changes; with wool it does, as is simply shown by the ease with which ordinary creases vanish when damped. Any structure largely dependent on hydrogen bonding is to some extent moisture sensitive, and even though it can be ironed dry, nylon falls short of the ideal. With Terylene the upper transition is higher and less dependent on moisture and crease setting is in consequence more permanent. Other thermoplastic fibres such as the acrylics, acetate and triacetate also have useful settability under heat treatment due to transition ranges which even in moist conditions are well above room temperature. No fibre reaches the perfection of zero hysteresis loss between wearing and washing temperatures and a large change in flexibility at ironing and setting temperatures, but Terylene is outstanding in that it combines low creep at room temperature and one of the highest transition ranges with high crystallinity, strength and abrasion resistance, all of which factors promote stability and durability.

Although strongly hydrophobic properties can be most useful they have certain disadvantages—for example, in the production of static electricity and associated problems of grease attraction and soiling. Fibres are, therefore, often classified according to their 'moisture imbibition'. This is the total molecularly-held water, expressed as a percentage of the dry weight of fibre, when a mass of fibres is saturated in distilled water and then

centrifuged at 1000 g. for five minutes. The values for some commercially available fibres are shown in Table 1.

TABLE 1

MOISTURE IMBIBITION OF TEXTILE FIBRES

	per cent
Standard viscose rayon	100
Wool	40
Cotton	50
Cellulose diacetate	35
Cellulose triacetate	10–16
Polyacrylics	8
Nylon 66	11
Terylene	3

It is clear, therefore, that the regenerated cellulose fibres are the most highly absorbent and in this respect are complementary to the synthetic polymer fibres. Such properties contribute substantially to the comfort of garments. Some regenerated cellulose rayons of high moisture attraction are, however, not particularly stable dimensionally unless chemically treated with the appropriate resins, or blended with thermoplastic fibres, or by both methods. Regenerated cellulose fibres are, however, very cheap and are therefore the most commonly used synthetic textile fibre. In Table 2 details are given of the consumption of different types of fibres, for the years 1938 and 1955.

TABLE 2

U.K. PER CAPITA FIBRE CONSUMPTION (LB.)

	1938	*1955*
Cotton	16·9	14·5
Wool	7·0	5·9
Rayon	2·0	6·4
Wholly synthetic	—	1·3

It must not, however, be thought that all regenerated celluloses lack strength, for studies of the coagulation process have led to methods of controlling the skin–core ratio and thus to the production of vastly stronger and more abrasion resistant fibres such as Strong Fibro, M95, Toramomen Z54 and Tenasco. Materials of this type are being used to make high quality poplins. A different modification of the spinning process is that in which a pigment is incorporated into the spinning dope, resulting in a very fast colour in the subsequent fibre. It is of interest to record that these spun colours confer a marked resistance to photodegradation, much better than that from a conventional fast dye. It has also been found that fabrics with improved wearing properties and generally enhanced serviceability, compared with 100 per cent cotton, can be obtained by using blends comprising one-third Fibro (viscose rayon staple) and two-thirds cotton. This information was obtained from extensive trials on men's knitted underwear, nurses' uniforms, overalls and Terry towelling, all of which receive severe washing. Blending with acetate rayon improves softness while the incorporation of triacetate enables durable creasing to be carried out. Finally, if resin treatments are to be used regenerated cellulose rayons are more receptive than cotton to these reagents. By these examples it may be seen that the clothing manufacturer can, if he wishes, specify a very wide range of performance requirements which the fabric manufacturer is able to meet by careful fibre selection or by blending.

High strength and an attractive feel are of course only two of the desirable attributes of clothing. Another important aspect is that of thermal insulation and it is probable that wool garments bought anywhere in the world are, no matter what attention is paid to appearance and durability, purchased with a view to keeping the wearer warm.

Human beings are warm-blooded creatures, and when at rest and unclothed are comfortable at an ambient temperature of 85° F. At temperatures lower than this the body feels chilly and, as the temperature falls heat is increasingly lost to the surrounding air, being provided by an increased rate of metabolism. Clothing must be worn to cut down this loss as the capacity of the metabolism to balance it is limited. Depending on physical exertion, however, the body is rarely in a 'steady state' and external conditions are also liable to vary widely and rapidly. The body may thus find itself becoming too hot in which event perspiration forms and any clothing must, as well as acting as an insulator, permit water vapour to pass to the outside.

Fibres are in themselves comparatively poor heat insulators. The best insulator is a still layer of air, and the best fibrous insulators are those which entrap air. Insulation of this sort by its very nature permits water vapour to pass from the skin to the outside. Any fibre which is crimpy and springy, not flattening when damp, provides ex-

cellent warmth, and apart from extremely expensive specialities such as cashmere, a soft wool garment is unsurpassed. Insulation breaks down when the air layer is removed either by being forced out by cold moving air (a wind) or by being wetted. Such movement can be prevented by having a very closely constructed fabric and it has been found that provided the fibres are sufficiently hygroscopic water vapour can still pass. Cotton is such a fibre and the ideal cold weather clothing comprises a loosely constructed inner wool garment, surrounded by a tightly woven outer cotton garment which can even be adequately waterproofed and still retain the ability to transmit moisture.

In our climate the provision of suitable hot weather clothing is generally less urgent. Evaporation of perspiration is assisted by wearing next to the skin loosely constructed garments which can absorb plenty of moisture. Good circulation of air within, to evaporate the moisture away from the skin, is important. The colour of the garment also has a significant effect as on this depends the ability of the fabric to reflect away the high temperature solar radiation; in this respect white fabric will reflect about two-thirds of the sun's radiation and black only one-tenth. Similar colours produced with different dyes may also differ greatly owing to different reflectance of invisible infra-red radiation. Colour has, however, a completely insignificant effect on the low-temperature radiation emitted by the body; in this respect all textiles behave like black bodies, with high emissivity. A bright metallic surface such as aluminium foil emits only about one-tenth as much, and experimental fabrics have been developed in the laboratories of the B.C.I.R.A. in which the material is coated with a film of aluminium metal and yet retains moisture permeability and adequate flexibility.

The ability of fabrics made from certain new fibres to take durable pleats has focused attention sharply on some shortcomings of traditional materials. Lack of permanence in creases, the necessity of ironing, the tendency to shrink, the frequency of holes in socks and the susceptibility to attack by moths are examples of faults in wool which have been accepted as inevitable. It is now becoming very clear that they need not be accepted, and the public is in these respects increasingly demanding vastly improved serviceability. An example of the change—and a very marked change it is—in what may be considered an acceptable standard is provided by the introduction of nylon-reinforced men's footwear with its greatly increased life.

Although some of these benefits have been brought about by the introduction of new fibres a great many others have been made possible because of new finishing techniques. The principles behind them are not always new; for example, it has been known for at least fifty years that treatment with certain oxidizing agents reduced the felting power of wool, and the first crease-resist fabrics appeared about thirty years ago. Early shrink-resistant processes were not particularly reliable but the insistence of the buyer on reasonable performance, and a better appreciation by the manufacturer of the need for process control has resulted in a number of excellent shrink-resist finishes. Examples include alkaline sodium hypochlorite together with either peracetic acid or potassium permanganate; permonosulphuric acid followed by sodium bisulphite; and 'activated enzymes'. These reagents function by modifying the scaly surface of the fibre and may thus have an adverse effect on the abrasion resistance. Consequently, increasing attention is being given to treatments with polymers which alter elastic properties or mask the scales and which can be expected to increase abrasion resistance.

Phenomena whereby fabrics are prevented from shrinking or, for that matter, prevented from taking up any undesirable form, come under the heading of 'dimensional stabilisation'. Wrinkles and creases in, for example, fine table linen are formed because the fibres are bent and twisted under stress and do not recover their original dimension when the stress is removed. Alternatively, the fibres may already be in a state of strain in the finished cloth, and without any stabilisation process, such as preshrinking, will shrink as soon as they are wetted and the strains are released. The early attempts to impregnate cellulosic fabrics with urea-formaldehyde precondensate, followed by polymerisation at about 130° C., were strikingly successful and introduced a new era of resin finishing. Modern methods are very similar except that different resins are being tried, the aim being to obtain a softer finish, which can also be achieved by incorporating other agents such as silicones. Such softer finishes also improve

the tear strength of the treated fabric. The presence of substantial amounts of resin in the fabric leads, logically enough, to a stability which is generally improved as well as being specifically improved with regard to creasing. Recent extensions of the finish have been in the direction of 'drip-dry' and 'non-iron' fabrics, though it is interesting to speculate on how long these would have taken to appear had it not been for the wide appeal of the non-iron, etc., nylon and Terylene counterparts. These processes often entail the use of a lower quantity of resin with an increased proportion of formaldehyde and, since the garments will have to stand up to a lot of washing, a wide range of resins has been studied with a view to obtaining improved wash fastness and lack of chlorine retention.

If clothes are to require less care a less frequent need for pressing will be one step in the right direction. The ability of fabrics made from nylon, Terylene and triacetate to take permanent pleats has a most powerful appeal for the consumer, particularly with regard to pleated skirts. This had the immediate effect of stimulating research into the production of all-wool fabrics which could be permanently pleated, and details have recently been published of two such methods. The Si-Ro-Set process has been developed in the laboratories of the C.S.I.R.O. (Australia) and involves spraying the cloth with a solution of ammonium thioglycollate at pH 7 and then pressing or pleating in the usual way. The dry cleaning organisations are showing particular interest in this method. In the second process (B.P. 775,486) the cloth is impregnated with sodium bisulphite solution as the last wet process in the finishing routine and is then dried at a low temperature. Applied in this way the bisulphite facilitates subsequent setting even though this may follow a long time afterwards, and a permanent crease is inserted as before by simple steam pressing. Similar permanent effects can be obtained in cellulosic fabrics by using suitable resins; the cloth is impregnated with the catalysed precondensate, dried, pleated and cured with pleats in position. If such a treatment is given with a friction calender instead of a creasing then a permanent glaze effect is produced.

A domestic routine which could well be dispensed with is that of diligently searching for moths and taking due precautions (probably of doubtful efficacy) to keep them away from wardrobes and other places of storage. In this respect mothproofing agents assist the trend towards 'easy care' and have in fact been known for many years, e.g. the Eulans (I.G.); Lanoc CN (I.C.I.) or Mitin FF (Geigy). These are comparatively expensive which may have limited their adoption, but newer reagents such as Dielmoth (Shell) are cheap. Dielmoth is now supplied in a form substantive from warm aqueous solutions and is both fast and effective; with due pressure from the consumer it could soon become impossible to buy a wool garment which has not been mothproofed.

A garment which is water-repellent may not be easier to care for—except that it will not require as much drying out—but for reasons of both comfort and health it is highly desirable. The wholly impermeable rubberised or plastic waterproof is either uncomfortable or fragile, but many acceptable showerproofing finishes for fabrics are now available (Fig. 1). The requirement is essentially for a shower-proof yet porous fabric which is unaffected by dry cleaning. Suggested reagents include oxymethyl pyridinium chlorides, water-repellent melamine resins, chromium stearic acid complexes and silicone resins. Of these the silicone resins have attracted most attention recently for they not only induce water repellency but also make the fabric softer. Moreover, the rather inconvenient method of application from a solvent has given way to the use of aqueous emulsions, and a recent innovation consists in incorporating an alkyl titanate into the silicone reagent which permits a marked reduction in curing temperature and gives an improved result. An interesting outcome of the silicone finishes lies in the reduction of the ease with which the fabrics can be soiled by aqueous stains; grease stains are, however, not affected. Treatment with a fluorinated polymer is the basis of the new Scotchguard finish which induces both oil and water repellency, thus being effective as an almost universal non-stain finish.

It is estimated that at any one time about 550 people are being treated as in-patients in hospitals as a result of clothing catching fire, the average period of in-treatment being 47 days. A high proportion of these casualties are young children and in terms of suffering the damage is appalling; hence, though fireproofing treatments do not in any sense come under the 'easy-care' heading they are of major importance. Where legislation is concerned,

this country has lagged behind America, but the public is undoubtedly becoming increasingly conscious of the risk inherent in certain fabrics, those mainly responsible being of a cellulosic nature, particularly with brushed and fluffy surfaces. It has unfortunately not proved easy to assess flammability. Following a detailed hospital survey, the flame-resistance rating (the time in seconds taken to burn 100 in. vertically) of fabrics has been related to the number of burn incidents in which the fabric was involved, and in the following table a total of 81 incidents are classified.

TABLE 3

Flame-resistance rating	*Number of incidents*	*Flame-resistance rating*	*Number of incidents*
15–20	3	50–55	9
20–25	1	55–60	9
25–30	5	60–65	2
30–35	10	65–70	1
35–40	16	70–75	2
40–45	10	75–80	1
45–50	10	130–135	1
		135–140	1

A number of cheap flameproof finishes have been known for some time but, not being fast to washing, are unsuitable for clothing, particularly as the most relevant garments are, for example, children's nightwear which requires frequent laundering. Modern recommended methods include the Lifeguard process, which utilises a combination of antimony and titanium oxy compounds; the Antiflam process in which antimony oxides and a chlorinated compound are employed; and the use of certain phosphorus compounds of which the most successful is tetrakishydroxymethylphosphonium chloride (T.H.P.C.). This is applied along with, *inter alia*, urea, triethanolamine and a trimethylol melamine resin and forms the basis of the Proban process. All the finishes named above are fast to laundering and give infinitely high flame-resistant ratings when applied to cotton or viscose rayon materials, i.e. the fabric does not burn at all. The search for new compounds would be simplified if more were known about the exceedingly complex reactions involved, viz. the thermal degradation of cellulose and the effect of associated proofing reagents.

And what of the future? Fabrics treated by

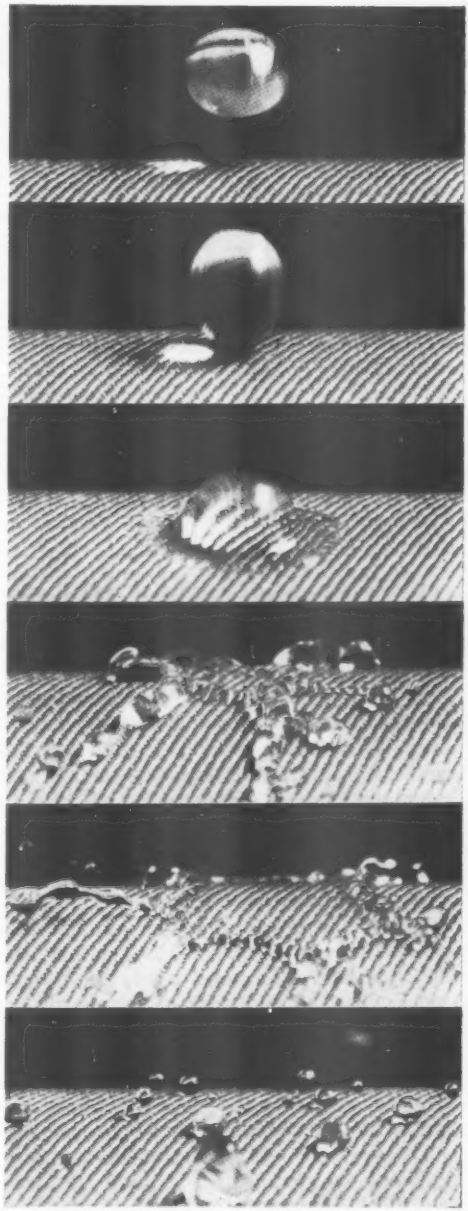


Fig. 1.—Photograph showing the scattering of a drop of water as it falls on a chemically waterproofed cotton gaberdine fabric. *(By courtesy of Ciba Limited, Basle.)*

processes such as are described above go far to meet present-day requirements, but there is no doubt that new demands on fabric performance will be made in the near future. There is an increasing desire for clothes which can be maintained fresh and clean by simple domestic washing machine techniques and with little or no ironing. This trend is already well-established with garments such as shirts and blouses, and the logical outcome of such a favourable reception will be a desire for minimum-care outerwear such as suits and coats. Provided that satisfactory collaboration can be maintained between cloth manufacturer and clothier there is no reason why, with the aid of new fibres and the immense range of finishes available, such garments should not be made.

The advent of new processes, each claiming to bring about some specific improvement, makes it imperative that the subsequent garments will in fact do what is claimed for them. No matter how it may improve a fabric, a finish always adds to the cost and insistence on 'value for money' is not likely to decrease. It is desirable that intelligent and comprehensive systems of labelling should be used more widely than at present; under such circumstances the consumer can buy 'quality tested' or guaranteed goods, which in due time should become almost universal.

TWO CULTURES AND THE SCIENTIFIC REVOLUTION

The current (March) number of *Cambridge Opinion* provides a most interesting commentary on Sir Charles Snow's plea for increased communication between scientists and non-scientists.

Sir John Cockcroft—in an article entitled 'Science in the University'—looks at the development of science in Cambridge since the war and considers the role of Churchill College. He comments in passing that 'it is not surprising that scientists are not "literate" and Arts' students not "numerate", for the specialisation of the sixth form exerts its pressure downwards in the middle school in a devastating way. There are many University teachers who would willingly sacrifice some of the excessive specialisation in the sixth form in favour of a broader base education to at least 16, together with a more satisfactory utilisation of minority time in the sixth form.'

The articles which follow attempt to answer such questions as: What does the research worker do in a laboratory from day to day? What keeps him going? Curiosity? Search for truth? What implications does he feel his work may have for the humanities? (See Mr. Feinstein's *Diary of a Laboratory Scientist*.) Do philosophy and politics have effects on the course of science? Why and how is the layman to be informed of what science is about? Dr. H. P. Zeigler, now working in the Department of Zoology at Cambridge, considers for example whether physics gives an accurate picture of what the various sciences are about and goes on to suggest that there is an attitude that is common to all the sciences.

The editors—assuming 'that it is both possible and worthwhile to teach undergraduates with no scientific background *about* science, about its methodology and its historical development'—outline some of the suggestions which have been made for reducing the barrier between students of the arts and students of science: the use of entrance examinations to bring about less specialisation in the sixth form; the one year *Principles of Science Tripos* based on intensive study of one area of modern science, paralleled by an examination of the historical development and philosophical assumptions of the scientific concepts introduced, and including laboratory, field and mathematical instruction where relevant; finally, and confessedly 'slightly radical' in outlook, there is the suggestion that undergraduates should be enabled to read two to three subjects in widely differing fields during their first year—it is accepted that this might tend to make the University a four-year course.

PROBLEMS OF THE MOON

By PATRICK MOORE, F.R.A.S., F.R.S.A.

Observational selenography began three and a half centuries ago, when Galileo turned his first tiny telescope toward the Moon. His views of the mountainous, crater-scarred lunar surface fascinated him, and the rough chart which he constructed is of some historical interest, though its accuracy is naturally low. Better charts were drawn up by his successors, notably T. Mayer, J. Mädler (with W. Beer) and J. Schmidt; later, the development of photography meant that the positions of lunar features could be measured with precision. Modern instruments are capable of showing extremely fine surface details; moreover the Moon is by far our nearest natural neighbour in space, and the virtual absence of an atmosphere means that its features always appear sharp and clear-cut. As G. de Vaucouleurs has pointed out,[1] even binoculars will show the Moon just as plainly as our greatest telescopes will show the planet Mars.

Under such conditions, we might reasonably expect our knowledge of the Moon's surface to be complete. Oddly enough this is not the case; many points remain to be cleared up, and in view of the rapid development of space research the matter is becoming urgent. In the present paper it is naturally impossible to deal with more than a few of these outstanding problems, but an attempt will be made to outline some of the trends in observational selenography.

First, it is interesting to try to decide whether the Moon's surface is entirely changeless, or whether minor alterations take place there. Mädler, whose lunar map published in 1837[2] is of amazing accuracy in view of the fact that it was compiled with the aid of nothing more powerful than a $3\frac{3}{4}$-in. Fraunhofer refractor, believed the Moon to be completely dead—a world where nothing ever happened, and had not done so for many millions of years. Many authorities are still of this opinion. At least there can be no doubt that major upheavals belong to the remote past, and even my suggestion, made in 1952,[3] that minor changes may possibly take place has met with considerable criticism. This criticism is justifiable, but recently the whole question has been reopened by the report that N. Kozirev has observed an outbreak inside the crater Alphonsus. This has received so much publicity, and has caused so much controversy, that it is worth describing in some detail, particularly as the situation is still far from clear. Various accounts have already appeared —for instance by Z. Kopal[4] and by D. Alter.[5] The information given here is drawn partly from a letter from Kozirev to myself [6] and partly from Kozirev's articles published in the United States in February 1959.[7]

Studies of the area were carried out some years ago by D. Alter, now Director Emeritus of the Griffith Observatory. Following examination of photographs of Alphonsus and the adjacent region taken at Lick in 1937, Alter considered it worth while to photograph the region in both infra-red and blue-violet. On the morning of October 26, 1956, under excellent conditions, he secured exposures which were of great interest. Alphonsus and the neighbouring crater Arzachel were well shown, but in blue-violet the western part of the floor of Alphonsus seemed to be more obscured than the corresponding area in Arzachel. Alter regarded this as an indication that small amounts of gas were being discharged from the tiny dark spots along some of the clefts.[8] It may or may not be significant that last-century observers had suspected minor disturbances in this area; for instance, H. Klein [9] described Alphonsus as one of the most active regions on the Moon, and in my exhaustive study of the literature I have collected several other similar accounts.[10] However, these

old visual observations cannot be regarded as reliable, and Klein at least was prejudiced in favour of lunar changes.

Alter's research came to the attention of Kozirev, who decided to carry out investigations with the aid of the 50-in. reflector at the Crimean Astrophysical Observatory. He commented that the lunar surface is exposed to all the hard radiation sent out by the Sun, and started to search for fluorescent effects due to a very tenuous localised 'atmosphere'. On the early morning of November 3, 1958,* he obtained what he regarded as positive results. While guiding a plate, he noticed that the central peak of Alphonsus had become blurred, and was apparently engulfed in a reddish 'cloud' which shifted noticeably. The slit of his spectrograph was extended in an east–west direction across the central peak, and when the spectrograms were developed they provided confirmation. I quote from Kozirev's letter[6]:

> On the spectrogram obtained at 1h. U.T., the peak of the crater appears redder than the adjacent floor; possibly at that time the peak was being observed and illuminated by the Sun through the dust thrown up by the eruption. On the spectrogram obtained at 3.00–3.30 U.T., the spectrum of the peak shows a bright gaseous emission. The most prominent emission bands are at 4756 Å (not yet identified) and the Swan band group, due to C_2 molecules, at 4735, 4713 and 4696 Å. Swan bands also occur at 5165 and 5130 Å. A group of C_3 lines from 4100 to 3950 Å is clearly visible, and there are many other lines which have not so far been identified. During the guiding of this spectrogram, I noticed a marked increase in the brilliancy of the area, and an unusual white colour. Suddenly the brightness began to lessen. I stopped the exposure and started a new one, from 3.30 to 3.45 U.T.; the resulting spectrogram showed the normal appearance.

The report was received with some incredulity by astromers in other countries, largely because it was generally unexpected; Mädler's picture of a totally inert Moon had been accepted for so long that an outbreak of this sort, however localized, involved a fundamental change of outlook. Yet Kozirev stated categorically that he had not only taken spectrograms of the phenomenon, but had watched it visually. Discounting the obviously absurd hypothesis of hoax or fraud, there were only two possibilities: either the outbreak had genuinely occurred, or else Kozirev had made a remarkable series of mistakes. In view of his considerable experience and excellent reputation, the latter did not seem likely.

Subsequent observations of the area were both confusing and contradictory. During November and December a reddish patch in the area concerned was reported by several observers,[11] and attributed by them to coloured material ejected at the time of the outbreak. Others completely failed to see the patch, and tended to dismiss it as being due to atmospheric dispersion in the Earth's air. This lack of agreement is most unsatisfactory, and further studies are needed. I can only comment that despite careful search, I have been unable to see a trace of colouration.†

Arguments about the whole series of observations will certainly continue for a long time to come, and as yet it is premature to come to any definite conclusions. It must however be added that if we accept the reality of the outbreak, we must conclude that the existence of pockets of heat under the lunar surface is probable. Moreover, reports of slight variations elsewhere on the Moon will be strengthened, and under the circumstances it seems worth while to pay some attention to these older reports.

The classical case is that of Linné, on the Mare Serenitatis. Up to 1843, the formation was described as a well-marked crater not unlike Bessel. In 1834 Lohrmann, one of the best lunar observers of his time, wrote that it was 'the second most conspicuous crater on the plain . . . it has a diameter of about 6 miles, is very deep, and can be seen under all conditions of illumination'.[12] Mädler gave a similar description, and so did Schmidt between 1841 and 1843. Yet on October 16, 1866, Schmidt found that the crater had apparently vanished, to be replaced by a white spot. His subsequent announcement was largely responsible for the re-awakening of interest in observational selenography.

The modern Linné consists of a small pit,

* Kopal, in his paper, Ref. 4, gives the date wrongly.

† On October 23, 1959, Kozirev reported fresh activity inside Alphonsus, and it is said that more spectrograms were taken. From 1h to 3h on that morning I was myself observing Alphonsus with an 8½-in. reflector, powers 300 to 400, and was unable to see any signs of activity, so that any new outbreak at that time was certainly beyond the range of the telescope which I was using.

roughly 1 mile in diameter, situated on a low mound or circular swelling. The associated white nimbus is visible with any small telescope, but the pit is too delicate to be seen with instruments of the aperture used by—for instance—Mädler. My observations made with the 33-in. refractor at Meudon indicate that the western wall of the pit is higher than the eastern, but in itself the formation is not particularly remarkable; neither is it unique. Other objects, such as a feature in the Mare Crisium, closely west of Picard, closely resemble it.

Acceptance of the pre-1866 observations means that a change must have occurred, but it must be remembered that few skilful observers with adequate equipment were engaged in selenography at that period. In this instance we have to depend solely upon the reports by Lohrmann, Mädler and Schmidt, and so here again the question remains open. If activity can be proved inside Alphonsus—or anywhere else on the Moon, for that matter—the hypothesis of alteration in Linné will be strengthened, but the modern trend is to regard it as dubious, despite the fact that even in its modern form the object is conspicuous by virtue of its relative isolation. There is little point in discussing other reported changes in various parts of the Moon, since the evidence is much more slender than in the case of Linné.

A fair summing-up is to say that major alterations on the lunar surface definitely do not occur, but that in two cases—Linné and Alphonsus—reports of minor activity are sufficiently convincing to merit close attention. At the moment, the wisest course is to preserve an open mind. However, if any trace of activity does linger on it must be 'volcanic', using the term in its broadest sense, and this brings us to the vexed question of the origin of the craters.

Various far-fetched theories to explain the surface topography have been put forward, but on the whole it seems that only two theories are worthy of serious consideration. The first supposes the craters to be igneous, though very different from terrestrial volcanoes. The second attributes them to the results of meteoric impact.

The meteor theory was originally proposed by F. Gruithuisen, a nineteenth-century German observer who possessed ability, but who tended to bring discredit upon himself because of his vivid imagination and wild interpretations. The theory

1937 Oct. 24 Age 20d. 04

The Linné region. (*Photograph by Dr. H. P. Wilkins, F.R.A.S.*)

was more or less forgotten, but was revived later by authorities such as G. K. Gilbert.[13] Nowadays it is widely supported, among its adherents being H. Urey, F. Hoyle and G. P. Kuiper. Much the best and most convincing account of it has been given by R. B. Baldwin.[14]

Igneous theories are of various kinds. Some, such as the famous 'volcanic fountain' of J. Nasmyth and J. Carpenter,[15] are clearly unsound, but others are more plausible, and special reference should be made to the long series of studies by J. E. Spurr.[16] Notes upon all the proposed theories, including the igneous and the meteoric, have been collected by A. Paluzie-Borrell, and published in a valuable monograph.[17]

Meteor craters occur on the Earth. The most famous of them is to be found in Arizona; it was discovered in 1871, and has been intensively studied. Its diameter is about 4100 ft. and its depth 570 ft., while the outside rim rises to something like 100 ft. A rather larger formation, almost certainly meteoric in origin, has been found in North Quebec, and investigated by V. B. Meen [18]

and others; meteor craters also occur in Australia, the Baltic island of Oesel, and elsewhere. Baldwin [14] has given an excellent account of them. Their relative scarcity may be explained by erosion, even though an extraordinary theory due to M. W. Ovenden,[19] to the effect that craters of this type 'would, in a few million years, be rubbed away by friction with the atmosphere as the Earth rotates underneath it', cannot be taken seriously. The surviving meteor craters are very small judged by lunar standards, and if the Arizona crater could be transferred to the Moon it would be regarded as a very minor feature; it would certainly not be afforded the dignity of a separate name.

The forms of impact explosion craters, meteor craters, and lunar craters have points of resemblance, though G. Delmotte [20] has maintained that a comparative study reveals significant discrepancies. It is also quite correct to say that artificial impact craters can be produced showing many of the features observed on the Moon. We also find igneous features which may be significant —particularly those at Richat, near Port Etienne in French West Africa, which have been described by T. Monod [21] and J. Richard-Molard,[22] and charted in the map drawn by E. Raisz.[23]

These features, of which the craters of Temimichat-Ghallaman, Ténoumer, Guelb-Aouelloul, Dôme des Semisyât, and Richat itself are the most prominent, are of two main types: single-walled craterlike depressions with diameters ranging from 500 to 1500 m., and large circular-shaped areas up to about 50 km. in diameter, in which a concentric disposition of alternating ridges and valleys is evident. The first are almost certainly volcanic; the second have been attributed to the denudation of dome-like geological structures formed in strata of contrasting hardness. So far, at least, no meteoric fragments have been found in the area, and a meteoric origin for the formations is most unlikely. Further surveys of them are desirable, but apparently they are basically 'lunar' in type.

Some volcanic features in other parts of the world also show points of similarity, and model lunar-type craters may be produced both by impact and by other methods. Therefore, terrestrial analogies can shed only limited light upon the problem of the Moon's surface moulding—a fact which is by no means always appreciated.[24]

The tremendous sizes of the lunar features are not easy to explain. The largest object conventionally classed as a crater is Bailly, which has a diameter of almost 180 miles, but it seems that there is no basic difference between a crater and a mare. The Mare Crisium, for instance, has an area of 78,000 square miles, which is much greater than that of the dark-floored crater Grimaldi (14,000 square miles), but it is difficult to avoid the conclusion that they were formed by the same kind of process. The Mare Humorum has less than twice the area of Bailly. The largest maria are sometimes of similar type; with Mare Imbrium, for example, the bordering ranges such as the Apennines and Alps seem to form the wall of the 'Imbrium crater'. It is worth noting that if Grimaldi happened to lie nearer the centre of the Moon's visible disk, it would probably have been classed as a minor mare—a point of view which I have not come across in any published works. There is in fact a complete range of mare-type formations with dark floors, from relatively small features (Crüger, Billy, Firminicus) through craters of moderate or large size (Plato, Grimaldi) to the maria. If we can explain the origin of any of them, we will at one stroke solve many of the problems connected with surface moulding.

Whatever be the past history of the Moon, there is little doubt that volcanic processes have operated there; it is also virtually certain that impact craters have been produced, as on Earth. In short, there must be both igneous and meteoric formations. What has to be decided is whether the main forces concerned were internal or external, or perhaps, as N. S. Shaler [25] originally suggested, a combination of the two.

Notice must be taken of minor features such as the domes, which are more common than has hitherto been realised; during the past few years I have been attempting to catalogue them, and several lists have been published,[26] but the work is still in its early stages. Plateaux also occur. Wargentin is the best but by no means the only example; others have been pointed out by C. F. O. Smith.[27, 28] Igneous action is certainly involved here, though it could possibly have been initiated by impact. Concentric craters of the Vitello type are interesting, and need to be explained. The existence of grid systems on the Moon has been known for some time; Spurr [16] referred to such

phenomena, and most valuable work on the subject has recently been carried out by G. Fielder.[29] In 1953, following a close visual study of the Mare Imbrium and other maria, I came to the conclusion that the apparently smooth, undulating ridges seem generally to form parts of the walls of much-eroded craters. Fielder has confirmed this photographically,[29] and has also produced evidence that wrinkle-ridges cannot be regarded as wave-frontsof solid lava.[30] It is clear that the crust of the Moon has been subjected to great internal stresses in the past.

The main objection to the impact theory, however, is that the distribution of the craters (with which may be included the crater-like maria, such as Crisium) is not random. Any casual study will show this, and the whole matter has been investigated statistically by L. La Paz [31] and others, who conclude that few of the large craters are meteoric.

Among the tens of thousands of craters on the visible part of the Moon, there are naturally many cases in which one formation disturbs another. It is a firm rule that in such instances, it is the larger crater which is disturbed by the smaller. A few exceptions (e.g. Burckhardt) have been suggested, but my own visual studies lead me to the conclusion that there are no exceptions at all—unless one includes bays such as the Sinus Iridum, which may be in a different category. The Burckhardt group, for instance, is highly complex, but when observed under suitable illumination it appears that there is no overlapping of a small crater by a larger one. This rule would be expected with igneous craters, since the major formations would be formed earliest, when the Moon was at its most energetic. If the craters were meteoric, there would be at least some departures from the rule.

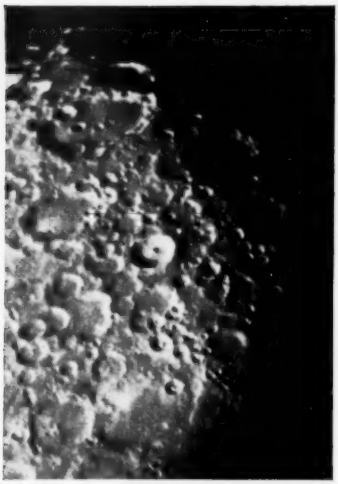
It is also significant that an interrupted crater may, and often does, show walls and floor which are apparently undamaged except at the precise point where the intruder has destroyed them. Thebit is an excellent example of this. In 1955 I argued that this is opposed to the impact hypothesis; each impact would cause a major 'moonquake' which would be certain to have far-reaching, not merely local, effects. In 1958 Kopal independently made similar comments.[32]

More significant still is the fact that the walled formations tend to be arranged in chains, which are best interpreted as lines of weakness in the original crust, along which craters were produced.

The Southern Mare Nubium. The prominent crater with a central peak in the upper right part of the picture is Tycho. At the bottom left appears the chain of three great formations, Ptolemæus (*lower*), Alphonsus (*middle*) and Arzachel (*upper*). (*Photograph by T. W. Rockham, 6-in. reflector.*)

These chains are well-marked. One, along the central meridian, includes the Walter group, the Ptolemæus group (of which Alphonsus is a member), and probably Clavius, W. C. Bond, Meton and the Sinus Æstuum; another, down the western limb, includes Furnerius, Petavius, Vendelinus, Langrenus, the Mare Crisium, Cleomedes, Endymion and De la Rue. Other chains are also in evidence, and each is composed of formations which are 'of widely different ages', to quote Baldwin.[33] If so, the impact theory must dismiss the chaining as due to pure chance.

Baldwin recognised this, and attempted to reject the chains themselves as being optical effects.[33] He pointed out that most of the chains



The area round the ray crater Tycho. (*Photograph by Dr. F. L. Jackson, 11¾-in. reflector, May 27, 1958.*)

are roughly parallel to the central meridian, and stated that since craters are at their most prominent when close to the terminator, the shadows 'force spurious groupings in the north–south direction'. However, this idea simply does not fit the facts, and a chart showing the larger craters only shows that the lining-up of the Moon's greatest formations is real. It is quite true that the greatest chains are more or less parallel to the central meridian, and this seems to indicate that the tidal pull of the Earth upon the young Moon played an important part in producing lines of weakness in the crust along which craters could form. I advanced this suggestion, with diffidence, in 1954[3] and in more detail in 1956.[34] It is quite unproved, and has not been properly worked out, but in any case it seems that the chaining presents obstacles to the meteoric theory.

Chaining is even more marked with the smaller craters and the craterlets. Strings of small craterlets are, indeed, remarkably common. In some cases the adjacent walls have been broken down; in others, however, they are preserved, and the 'moonquake' question is again significant. Many of the so-called clefts are really crater-chains either totally or in part. This applies, for instance, to the Hyginus Cleft, which is not a pure crater-chain, but which has craterlike enlargements along much of its course, the largest member being Hyginus itself.

H. Urey has discussed[35] the Rheita Valley, and attributes it and similar objects to 'high-velocity nickel-iron objects originating within the planetesimals that formed the collision maria'. He quotes G. P. Kuiper's view that the Rheita Valley is a crack caused by meteoric impact. Unfortunately for these hypotheses, the Valley is neither a true valley nor a crack; close visual studies reveal that it is a crater-chain, and could not possibly have been formed by the methods suggested by Urey or Kuiper. The Alpine Valley may be in a different class, but here we have parallel and transverse valleys, difficult to record photographically and to be seen visually only under ideal conditions of lighting. I first noted them in 1949, and they have since been fully confirmed by Fielder.[36] This argues against the Valley having been formed by a missile slicing through the mountains, though it provides no positive proof. On the other hand some of the 'splash-craters' radiating from Mare Imbrium as a centre do look as though they have been produced by impact, though the missiles may not be meteoric—they could have been ejected from the Mare site during the process of formation by internal action.

A further point of interest is that there are many cases of rounded hills crowned by summit craterlets, nearly always central or symmetrical. Baldwin[37] attributes these to chance hits. When his book appeared in 1949, a dozen such objects were known, and random bombardment indicated that there should be just about this number; Baldwin wrote that 'The agreement is excellent. The case for the meteoritic nature of the lunar craters is even more solidly founded, and the volcanic hypothesis is correspondingly weakened'. However subsequent observations, some of which have been made by the present writer from Meudon,[38] have revealed many more, and the total number now known exceeds fifty. Typical examples are the central peaks of Römer and Alpetragius. For the domes, my preliminary findings indicate that summit pits are the rule rather than the exception. In 1959 G. P. Kuiper, using the 82-in. McDonald reflector, announced the discovery of over a dozen such objects, which he describes as 'extinct volcanoes'.[39] Apparently, all Kuiper's objects are included in my earlier published lists.[26]

Here again we have obvious non-random distribution, and this is the pattern all over the Moon. Of course, the arguments are by no means conclusive. Mechanisms have been suggested to explain phenomena such as chaining and summit pits while still retaining the meteoric hypothesis. Such arguments are not, however, completely satisfactory.

The lunar rays are difficult to explain on any theory, but it seems that the meteor hypothesis is in the most trouble. An impact origin shows that the ray-craters must be the youngest formations on the Moon, since the rays pass over all other objects. In this case it is hard to see how the formation of a ray-crater in a crowded area, such as Tycho, has left its neighbours comparatively undamaged, in view of the tremendous magnitude of the 'moonquake' which would undoubtedly have been caused.

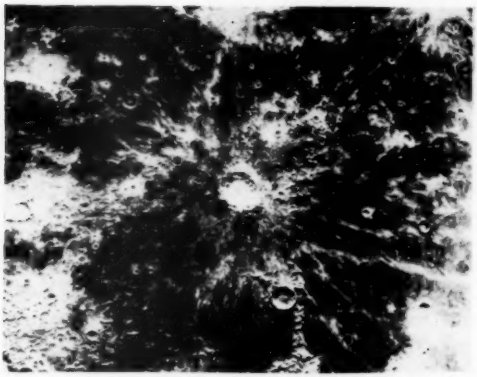
But if the impact theory has serious drawbacks, so have all forms of igneous hypotheses. I have made some suggestions,[34] but these will not be discussed here, partly because space forbids and partly because they are in any case tentative and uncertain. The most we can say at present is that if we reject the meteoric origin for the majority of the large formations, as I am personally inclined to do, then the craters can be due only to the release of forces within the lunar globe. The whole question, like so many others in connection with the Moon, is still completely open.

We are also largely ignorant about many of the characteristics of the surface itself. Temperatures have been measured, notably by Menzel [40] and by Pettit and Nicholson [41] and the results have yielded some information about the nature of the surface layer.[42] The surface layer is a poor conductor of heat, and is likely to be composed of dusty or ashy material instead of being bare rock. Recently, N. Barabashev and A. Chekirda have suggested [43] that the Moon is covered with a layer of disintegrated tufa-like rock, with grains ranging from 3 to 10 mm. in diameter.

Microwave radiation from the Moon was first detected in 1946 by Dicke and Beringer, using a wavelength of 1·25 c., and in 1949 an important series of observations at the same wavelength was carried out by Piddington and Minnett.[44] Troitsky and Zelinskaya used 3·2 c. in 1952,[45] Akabane 10 c. in 1955,[46] and more recently Gibson has used 8·6 m.[47] Derived temperatures reach a maximum appreciably after full moon, as is to be expected. The depth of the dusty or ashy layer is, however, most uncertain. Gold holds the view [48] that the layer is extremely deep, and has even suggested that 'space-travellers of the future will simply sink into the dust with their gear'. On the other hand, calculations by Piddington and Minnett [44] and by Jaeger [49] on the effect of a thin dusty or ashy layer overlying solid volcanic rock, according to a model proposed by Jaeger and Harper,[50] shows agreement in the case of a layer only a few millimetres thick. On the whole it seems rather unlikely that the layer is of great depth, though once again it is premature to come to any definite conclusions.

The problem of the existence or non-existence of a general lunar atmosphere has also been raised once more. Observational results demonstrate that there is an upper limit of about 10^{-8} for the ratio of gas over the Moon to that over the Earth, but it now seems that the real density is far less even than this. In 1949 Y. N. Lipski announced [51] that by polarimetric methods he had detected a tenuous mantle with a ground density of about 1/10,000 of that of the Earth's atmosphere, but this result has not been confirmed by later research along the same lines. Observations of the occultation of a radio source by the Moon have led G. P. Kuiper to suggest [52] the possibility of an atmosphere of density about 10^{-13}, and similar investigations have been carried out by Elsmore and Whitfield.[53] All this is naturally very tentative and uncertain. If such a mantle exists, it may well consist of helium and argon produced by radioactive processes in the lunar rocks, and may not be permanently retained by the Moon. In any case, it seems that any lunar atmosphere is to all intents and purposes negligible.

Obscurations in certain regions have been reported from time to time—for instance, by Charbonneaux in 1902 [54] near Thætetus, and by Thornton in 1945 [55] near Herodotus. Haas [56] has listed a number of examples, and obscurations have been suspected in connection both with Linné and the interesting Linné-type spot west of Picard. However, even if proved, these phenomena would be no indication of the presence of a general atmosphere, and speculation is pointless so long



The lunar crater Copernicus, a centre of a system of bright rays.

as the reality of the phenomena themselves remains so uncertain.

In the light of modern knowledge, it is even more pointless to waste time in discussing possible life on the Moon. Thirty years ago W. H. Pickering was still writing in support of his theory that 'moving patches' inside Eratosthenes were due either to vegetation or to swarms of living creatures, and more recently there have been suggestions that certain minor features inside craters of the Aristarchus type might be due to plant life. Nowadays, however, it seems quite safe to reject all such ideas. The evidence indicates that the Moon is entirely lifeless, and will remain so until men from our own world reach it.

Owing to the Moon's captured rotation, 41 per cent of its surface is permanently turned away from the Earth; and until the development of rocket research, this part of the Moon remained unknown. The only information came from rays, similar to those associated with familiar craters such as Tycho and Copernicus, but which came across the lunar limb, so presumably originating at craters on the averted hemisphere. In the nineteenth century, N. S. Shaler plotted six possible centres. Further studies were carried out in the 1930's by E. F. Emley, and later by H. P. Wilkins and myself. In 1954 Wilkins published a chart [57] showing several further ray-centres, on the Moon's hidden side. Yet these positions were most uncertain, and the limb rays themselves were very hard to plot.

In October 1959, the Russian vehicle Lunik III passed beyond the Moon, and sent back photographs of the quondam unknown regions.* The pictures showed that, as expected, the remaining 41 per cent of the lunar surface was basically similar to the area which we have always known. Large maria seemed to be absent, but there were smaller dark plains, together with a long chain of peaks (the Sovietsky Mountains) and a number of objects which appear to be craters. It is possible that one of these craters, known as Tsiolkovskii, is one of the previously-suspected ray-centres.

It is satisfactory that the rocket pictures are good enough to establish the existence of definite features. The Soviet authorities have allotted names, and these should certainly be accepted throughout the world. The flight of Lunik III was a superb technical achievement, and no praise can be too high for the Russian scientists who made it possible.

Information of all kinds has been sent back by the Luniks and similar rocket probes. For instance, it seems that the Moon has practically no magnetic field. This result was by no means unexpected, but it is certainly significant.

In the near future, it will certainly become possible to bring down an unmanned rocket on to the lunar surface, sufficiently gently to avoid destroying the instruments carried.[58] Manned spaceflight lies further ahead, but few authorities now doubt that it will be achieved.

In this paper I have been able to touch upon only a few of the many branches of selenography, and it has been natural for me to confine myself mainly to matters in which I am particularly interested. I hope that at least I have managed to convey some idea of how little we really know about the Moon. We are uncertain whether the surface is changeless, or whether minor activity still occurs; we do not know how the maria and craters were produced; we are largely in the dark as to the precise nature of the surface layer, and we cannot be sure whether or not a trace of atmosphere lingers on. It is true that in the universe as a whole, the Moon is a body of entire unimportance; but it holds a special fascination for us, and the modern observational selenographer has plenty of work to do.

* This paper was delivered in September 1959, before the launching of Luniks II and III. At the time, I speculated as to the possibility of experiments of this kind being carried out 'in the very near future'. For publication, the relevant five paragraphs have been amended so as to bring them up to date.—AUTHOR, December 9, 1959.

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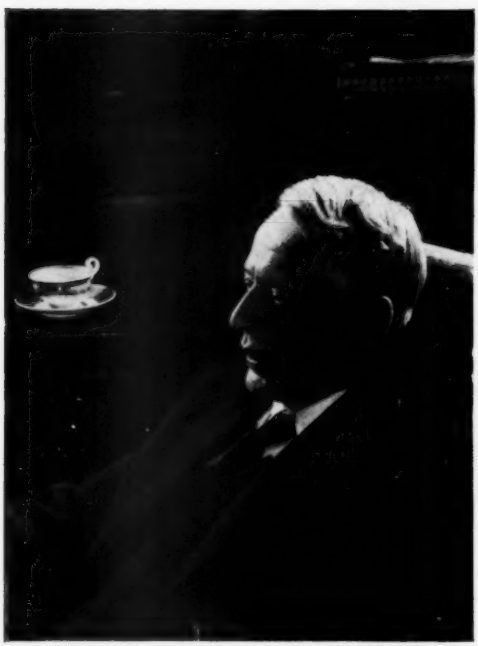
SIR GEORGE THOMSON, F.R.S.— PRESIDENT OF THE ASSOCIATION

The President

George Paget Thomson was born in 1892, some four years before his father, the immortal 'J. J.' Thomson, discovered the electron. Springing from this great tradition of British scientists, and a Nobel Prize Winner in his own right, George Thomson's whole career has been in the van of the most striking new developments in science, from the early days of flight, to the present search for thermonuclear power; he has moved in and influenced the world of government and international politics, and he believes in the popular exposition of science and can do it very well himself, as his book *The Foreseeable Future* has shown.



Sir George Thomson, F.R.S. *(by courtesy of Eugene Kammerman and 'Saturday Evening Post'.)*

Born and brought up in Cambridge, and since 1952 Master of Corpus Christi College, he regards that city as his home. But it was at Aberdeen (1922–30) that he carried out the work on the behaviour of the electron that later earned him the Nobel Prize, and as Professor of Physics at Imperial College (1930–52) that, his interest shifting to the neutron, he began to realise the possibility that an atomic bomb could be made. In the summer of 1940 he was back at the Royal Aircraft Factory at Farnborough (where he had spent the greater part of the First World War) working on methods of sweeping magnetic mines from the air, when it was suggested to him that if you separated the 235 isotope of uranium, you would get a violent explosion. Thomson felt this to be true and he was made Chairman of the British Committee set up to investigate the possibility of an atomic bomb. This Committee reported in 1941 that a bomb was possible and he was authorised to give this report to the American scientists Bush and Conant. During the next year, as Scientific Liaison Officer at Ottawa, he was in close touch with the American atom-bomb effort. On returning to England he was appointed Vice-Chairman of the Radio Board and later became Scientific Adviser to the Air Ministry.

To the Presidency of the British Association is added a formidable list of other appointments—President of the Institute of Physics, Chairman of the Cambridge University Appointments Board, Consultant to the Atomic Energy Research Establishment, to name a few—to all of which he brings the robust and universal viewpoint that will be so immensely valuable to the British Association in 1960.

BRITISH ASSOCIATION NEWS

Annual Meeting at Cardiff
August 31 to September 7, 1960

Sir George Thomson will preside over the British Association when it returns to Cardiff this summer after an interval of nearly forty years: the outstanding nature of his scientific achievements and the insight with which he illumines a world transformed by science eminently qualify him to do so. The theme of his Inaugural Address on *The Two Aspects of Science* makes straight for what must be the heart of the matter for the generation in which we live—what science has done to its creators and inheritors: its effect on the one hand on man's environment and, on the other, on his thoughts and sense of values.

This awareness of the close relationship between science and the 'human situation' will be further emphasised by a major innovation in the programme of the Annual Meeting at Cardiff this year. The whole of Monday, September 5, will be devoted to a review by a number of world-famous scientists and experts of the issues arising out of the world food and population situation today—issues so far-reaching and of such general concern that all members are invited to take part.

The main scientific programme is arranged by fifteen sections representing the many different branches of modern science. Here again Cardiff is breaking fresh ground, for the new Sociology Section, called into being at the York Meeting last year, will launch its first programme this year under the Presidency of Prof. D. V. Glass, Professor of Sociology in the University of London.

Apart from the Presidential Addresses, which will range over such topics as: 'Chemistry is not enough?' 'Tropical climate and biology', 'The peasant and the past', and 'Stellar motions', highlights of the Section programmes will include the Kelvin, Darwin and Lister lectures, inaugurated last year, and designed to encourage younger scientists to report in language intelligible to non-specialist audiences the nature of their work and the significance of their conclusions. The programmes of Sections will be arranged, as far as possible, to avoid clashes of subject and interest so that members may plan their week fully. Topics for discussion this year include 'The results of I.G.Y.', 'What mathematics is about', 'Advances in lunar and planetary astronomy', 'Polymer chemistry', 'Glacial geology', 'The environment and high blood pressure', 'Speech and language', 'The continuous casting of steel' and 'Monetary policy in Great Britain'. It is interesting also to see at how many points the Section programmes will touch on the World Food theme: 'Methods of refrigeration, and 'Sterilisation by radiation' (Section A, Physics); 'The productivity of the sea' and 'Genetics and world food' (Section D, Zoology, and K, Botany); 'Food supplies in the ancient world and among primitive peoples today' (Section H, Anthropology), not to mention the whole of the programme of Section M (Agriculture), which has been planned throughout to support and amplify the papers and discussions taking place in the World Food and Population Symposium on September 5.

In co-operation with the Director of Education in Cardiff, a special programme for schoolchildren in the area will be staged in conjunction with the main Annual Meeting. Illustrated lectures by leading scientists will be given on the afternoons of Thursday, Friday, Monday and Tuesday; local schools will present a Science in Schools exhibition; the Open Forum, which proved such a success in Glasgow and York and at which it is hoped that parents will also be present, will be repeated this year on the evening of Thursday, September 1.

Cardiff and its hinterland provide a wide choice

of excursions to places of local, scientific and industrial interest and a full programme of such excursions is being arranged as part of the Meeting. For those who like to make expeditions of the eye and mind alone, there will be daily screenings of outstanding scientific films on such diverse subjects as space flight, zoology and electronics.

The warm hospitality with which Cardiff plans to welcome members of the Association will include Civic and University receptions, an orchestral concert and (once more with the younger members in mind) a dance on the Saturday night. Relaxations such as these remind us that *dulce est desipere in loco* (despite those old Puritanical cries of 'beanfeasts' and 'junketings') is one of the pleasantest of the old traditions alive in the British Association today.

A Preliminary Programme—already published—contains an outline of the arrangements for the Annual Meeting including membership registration forms and details of the accommodation available. The Secretary of the Association will be pleased to send copies of this programme free of charge to all enquirers.

* * *

Presentation of Science throughout the Year

From the start of the new activities of the British Association, it was planned to establish Area Committees in all parts of the country, for the development of the lecture service, for the Young People's Programme, and for whatever other activities might be suggested by experience. The first three 'pilot' Committees were formed in 1958 in the north-east, based on Newcastle upon Tyne, Durham, and Billingham. They presented their first programmes during the autumn and winter of 1958–9; immediately it was seen that the idea was working, and that the pattern was on the right lines, steps were taken to establish other Committees. Cornwall, Northern Ireland, Nottingham, Sheffield, Norwich, Birmingham, Bradford, Aberdeen and Glasgow Area Committees came into being during 1959. Projects for other Committees based on South Wales, Colchester, York, Hull, Dundee, Edinburgh and Southampton are in various stages of development.

A full list of Area Committees, together with their Officers, is given at the end of these notes. It seems appropriate, in this first number of the new *Advancement of Science*, and as a tribute and an expression of gratitude to all those who are doing so much to make the work of these Area Committees not only possible but extremely successful, to report six notable recent 'first occasions' in these new British Association activities.

In October and November last year, the University of Glasgow Department of Extra-Mural Education, in collaboration with the British Association, organised a series of fourteen scientific lectures for adult and school audiences in the Western Isles and Highlands. There were four lectures in Islay (at Bowmore and Port Ellen), three in South Uist (at Daliburgh and Balivanich), two at Tobermory, two in Barra, one at Scarinish in Tiree and one at Oban. A second lecture at Oban had to be cancelled because the steamer was delayed. The speakers were Prof. R. Miller ('Man and the land'), Prof. M. F. M. Meiklejohn ('Bird life in the Western Isles'), Dr. H. Barnes ('Underwater television'), Prof. T. N. George ('Geology of the Highlands'), Dr. C. A. Hopkins ('Life and death in Tropical Africa'), Dr. A. Kent ('Space travel'), and Mr. A. L. F. Rivet ('Archaeology').

The audiences totalled over 700, but the success and importance of the programme were by no means to be measured by the numbers attending. In some cases the audiences had gathered from miles around. It was the first time they had had a chance of hearing a scientific lecture for years, and their keenness was remarkable and most rewarding. The speakers all felt they had participated in a programme of rare importance.

Shortly afterwards the Glasgow Area Committee of the British Association was formed, largely for the purposes of the Young People's Programme. As their first venture, to publicise the establishment of the Committee and its programme, they took a stand at the Fifth Scottish Schoolboys' and Schoolgirls' Exhibition at Kelvin Hall, from March 22 to April 2. As an attraction for the stand, Messrs. Ericsson Telephones very kindly lent their electronic game 'Daedalus', together with an engineer to explain the game and ensure that the machine remained unbeaten!

As the result of discussions last year with the Association of Teachers in Colleges and Departments of Education, a number of lectures and several series were arranged for Training Colleges. The first series was four lectures for the Wrexham Training College, the speakers being Dr. G. O. Phillips ('Science in the world today—what a non-scientist should understand and why'), Dr. T. R.

Kaiser ('The Universe revealed by astronomy, a wide introduction to astronomy'), Mr. G. Ratcliffe ('Space, and what we may learn from space research'), and Mr. T. Farrimond ('The human brain with reference to some recent research of special interest to future teachers'). There have also been series of three lectures for the Borough Road Training College, Isleworth, Middlesex, given by Mr. Ritchie Calder, C.B.E. ('Why teach science in secondary modern schools'), Dr. Freitag ('Friction'), and Dr. N. Tinbergen ('Animal behaviour'). and of five lectures for the Hereford County Training College, in which the speakers were Prof. D. L. Linton ('World population and food supplies'), Dr. McDonagh ('Radio astronomy'), Prof. L. S. Palmer ('The evolution of man and modern methods of study'), Dr. J. Fremlin ('Power, hope and energy'), and Dr. W. E. Swinton ('The significance of modern scientific research and its impact on society').

The success of these first ventures has fulfilled the high hopes expressed in the first discussions with the A.T.C.D.E., and it is hoped that there will be many more of them for other Training Colleges.

The Tees-side Area Committee arranged on December 14 the first Christmas Lecture for Middlesbrough schools. This followed the pattern of Christmas Lectures elsewhere. Prof. J. Rotblat spoke to 400 sixth-formers on 'Atomic energy, the public and the nation' at the Constantine College. Messrs. Head Wrightson gave much assistance in the organisation of the lecture.

The Cornwall Area Committee which gave the first big programme for schools in March 1959, organised their first large-scale public lecture for adults in the Town Hall, Truro, on January 28. There was an audience of nearly 800 to hear Prof. H. Bondi lecture on 'The structure of the Universe', and they were delighted and enthralled by the lecture. It was said to be quite the most successful scientific occasion in Cornwall for many years. Air Marshal Sir John Tremayne, Chairman of the Area Committee, was in the chair, and Lt.-Col. Sir Edward Bolitho, K.B.E., C.B., D.S.O., the Lord-Lieutenant, proposed the vote of thanks.

The Belfast Area Committee held their first meetings on February 9 and 10, when Sir Lawrence Bragg, F.R.S., lectured to 1500 sixth-formers in the Whitla Hall on the Tuesday, and to a similar audience of 600 in Coleraine on the Wednesday. His subject was 'How we hear and speak', and the lecture was illustrated with the inimitable Royal Institution demonstrations. Dr. Michael Grant, the Vice-Chancellor of Queen's University, took a lively interest in the whole occasion, and occupied the chair for the lecture in the Whitla Hall.

The recently formed Aberdeen Area Committee, which is representative of all seventeen secondary schools in the city, held its first function on February 26, when Mr. W. Moser lectured to 250 young people in the hall of the new Chemistry Department of the University. This was followed on March 18 by a lecture to 370 young people by Dr. Fraser of the Marine Research Laboratory, Torry, after which the audience, in four parties, visited the Laboratories. The combination of lecture and visit was particularly successful. Aberdeen also have another idea which may prove valuable and of much wider application. They have asked for advice on the preparation of a programme of scientific films, prints of which could be made available for about a month, so that the films could be screened in every school in the city, to audiences totalling about 10,000. Such a large audience obtained in one month from one print of a film may prove most welcome to producers of films, particularly industrial producers.

* * *

Area Committees of the British Association

Newcastle upon Tyne

AREA: Tyneside, Northumberland, Cumberland and Westmorland.
CHAIRMAN: Emeritus Prof. G. R. Clemo, F.R.S.
TREASURER: Mr. B. W. Abrahart, Director of Extra-Mural Studies, Joseph Cowan House, 153 Barras Bridge, Newcastle upon Tyne, 1.
JOINT SECRETARIES: Mr. A. P. Miller, Mr. R. D. Harrison, Department of Extra-Mural Studies.

Durham

AREA: County Durham, between Tyneside and Tees-side.
CHAIRMAN: Prof. D. H. Valentine.
SECRETARY: Mr. H. J. Boyden, M.P., J.P., Director of Extra-Mural Studies, 32 Old Elvet, Durham.

Tees-side

AREA: Co. Durham, south of a line from Middleton-in-Teesdale to the coast north of West Hartlepool, excluding Bishop Auckland; the North Riding of Yorkshire north of A170 and A61, and east and north-east of A1 and A66.

CHAIRMAN: Dr. I. J. Faulkner.
JOINT SECRETARIES: Dr. J. W. McAnuff and Mr. G. W. Ettle, I.C.I., Billingham Division.

Cornwall

AREA: The Duchy of Cornwall.
CHAIRMAN: Air Marshall Sir John Tremayne, K.C.B., C.B.E., D.S.O., J.P.
VICE-CHAIRMAN: Mr. J. E. Montgomrey, Hon. Secretary, Royal Institution of Cornwall, Truro.
SECRETARY: Mr. C. S. Smith, Vice-Principal, Cornwall Technical College, Trevenson, Pool, Redruth.

Northern Ireland

AREA: The Province of Ulster.
CHAIRMAN: Prof. Estyn E. Evans.
SECRETARY: Dr. J. F. Gillies, Vice-Principal, College of Technology, Belfast, 1.
TREASURER: Mr. S. E. T. Allen, Ulster Bank, 138 Great Victoria Street, Belfast, 2.

East Midlands

AREA: The area of the Department of Extra-Mural Studies of Nottingham University, i.e. most of Derbyshire, all of Nottinghamshire and Leicestershire and Lincolnshire.
CHAIRMAN: Prof. L. F. Bates, F.R.S.
SECRETARY: Mr. H. C. Wiltshire, Director of Extra-Mural Studies, 14–22 Shakespeare Street, Nottingham.

Sheffield

AREA: The area of the Department of Extra-Mural Studies of Sheffield University.
CHAIRMAN: Mr. W. H. Wilcockson.
SECRETARY: Dr. H. D. Turner, Department of Extra-Mural Studies, The University, Sheffield, 1.

Norwich

AREA: Norwich and district.
CHAIRMAN: M. W. Bulman, Esq., M.D., M.S., Lord Mayor of Norwich.
SECRETARY: J. W. Beeson, Esq., Director of Education, Education Office, City Hall, Norwich.

West Midlands

AREA: The area of the Department of Extra-Mural Studies of the University of Birmingham.
CHAIRMAN: Dr. Maurice Cook, C.B.E.
VICE-CHAIRMAN: Prof. P. Sargant Florence, C.B.E.
SECRETARY: Mr. E. A. Knight, Secretary, The Birmingham and Midland Institute, 1–18 Paradise Street, Birmingham, 1.
TREASURER: Mr. E. Hancock, Messrs. Jack Cotton and Partners, Waterloo Street, Birmingham, 2.
CHAIRMAN OF EXECUTIVE: Dr. T. Emmerson, Messrs. Guest, Keen and Nettlefolds.
EDUCATIONAL ADVISERS: Mr. T. J. Pickvance and Dr. H. V. Stopes-Roe, Staff Tutors in science at the Department of Extra-Mural Studies, Birmingham University.

West Riding

AREA: The area of the wool industry in the West Riding of Yorkshire.
CHAIRMAN: Sir Geoffrey Burton, K.C.S.I., K.C.I.E.
DEPUTY CHAIRMAN: Dr. E. C. Edwards, Principal, Bradford Institute of Technology, Bradford, 7.
SECRETARY: Dr. W. Guy, Bradford Dyers' Association Ltd., Central Laboratories, George Street, Bradford, 1.
TREASURER: Mr. N. Ellse, Messrs. Sandoz Products, 152 Canal Road, Bradford.

Aberdeen

AREA: Aberdeen and district.
CHAIRMAN: Mr. James Stewart, M.A.
SECRETARY: Mr. James Munro, M.A., Principal Teacher of Science, Old Aberdeen Secondary School.
TREASURER: Mr. Alexander Menmuir, B.SC.

Glasgow

AREA: The area of the Department of Extra-Mural Education of Glasgow University.
CHAIRMAN: Prof. T. N. George.
SECRETARY: Mr. J. Trump, Director, Department of Extra-Mural Education, Glasgow University.

THE ROAD AND RAIL QUESTION*

By Sir REGINALD WILSON *British Transport Commission*

1. Less Propaganda and more Science

It has often seemed to me, in recent years, that an efficient and economical transport system is rather like Salvation. We are all in favour of it, but few are prepared to accept the uncomfortable disciplines and ideas which alone will ensure it.

Our land transport in this small and crowded island depends almost entirely on five species of carriers—the train, the bus, the heavy lorry, the light van and the private car—and these carriers in turn depend upon some 200,000 miles of 'right-of-way', of which about nine-tenths is ordinary road and one-tenth is railroad.

The Americanism 'railroad' is useful, for the railroad is merely a specialised and highly-mechanised version of the ordinary road. The traffic moving over it must collect itself into large units called trains, which are then 'put through' under a high measure of discipline—the guiding rails, the signalling, the planned timetables, and movement control generally. This somewhat sophisticated apparatus may be expensive, but at least it gets the traffic through. Nearly one-half of our freight is moved over this specialised one-tenth of way, and perhaps about a fifth or a quarter of the passenger traffic (at high average speeds). Notwithstanding great peaks of demand, the discipline holds down congestion, though at many points the railroad system needs modernising if the throughput is to match current requirements.

As to the ordinary roads, delay and congestion are already heavy, and look like being heavier still. There is, also, a rising preference for private or personal transport as distinct from public or 'collective' transport. This preference affects bus and road haulage operators as well as railway operators.

* Synopsis of a paper entitled 'The Economics of Transport' presented to the York Meeting of the British Association.

More and more of our public transport undertakings are being edged into a position where higher charges or poorer services seem the only remedy—which leads to ever more private transport on the roads.

We are told that to cope with the increasing difficulties of movement, and to satisfy the ever-growing demand for better transport facilities, and especially for personal transport, society must expect to have to invest sums amounting to £7,500,000,000 for the expansion and improvement of road and rail transport (excluding current replacement) during the next ten years of so. A brave figure, of which over 90 per cent is for road and under 10 per cent is for rail. Included in the road figure are the additional road vehicles and so forth, but also £3500m. for 'track'.

It is hardly surprising if people feel that the time has come when society ought to have proper criteria by which to regulate its investment in transport, and judge the real cost of its policies on the Road/Rail Question, including any rise in *standby* costs inflicted on the essential public services. This is not to hint that an affluent society shall not be allowed the facilities which it demands. On the contrary; but we do need a less partisan approach, less emotion, less propaganda, less wishful and indeed illegitimate figuring.

This, then, is my first point—the absolute urgency of a more scientific approach and attitude of mind.

2. Need for a New Accounting

My second point is that the study of the Road/Rail Question calls for an accounting or reckoning on a new basis, a *social* accounting. What are the costs truly entailed to society in terms of man-hours, consumption of fuel and other material resources used up by each species of transport

service, compared with the benefits it produces to society?

The accounts of the carriers themselves are no sufficient guide. They exclude imponderable costs of considerable importance (e.g. safety, amenity, etc.) and the costs which do appear in their books are highly distorted and unequally weighted by taxation such as fuel duty, by legacies from the past such as obsolescence, inadequacy, or great, great burdens of debt, by a vast complex of public regulation and obligation which doubles or trebles the cost of some of the services demanded by society, and last but not least by the totally different bases on which society charges road carriers and rail carriers for their right-of-way. As to the earnings side of the carriers' accounts, often enough the receipts are controlled and limited by the public regulation upon which society insists.

We must try to search out the economic realities. There are obvious difficulties but a useful start can be made if we take the two sides of the account separately.

3. Primary Division of Social Costs

On the costs side, the costs of *Carrying* must be clearly distinguished from the costs of the many grades of *Track* over which the various carriers may have to move. Carrying cost and track cost are distinct in nature and object. The carrying is done by large numbers of individual operators, public and private, and there is often a good deal of competition about it, whereas the track—both road and rail—is provided by the State or by a State-created authority, and is inevitably a natural monopoly.

The carrying cost, also, is mainly a 'specific' cost, validly imputable to a particular service or group of services, whereas track cost over wide areas is an 'overhead' or community cost. It is often difficult even to define the area or unit in respect of which the track cost should be computed; arterial roads, feeder services, terminal facilities—all these can be linked together or not, as the case may be, and any calculation is greatly influenced by what we decide.

Or again, the cost of carrying is mainly a current cost in manpower, whereas the cost of providing the *existing* track lies mainly in the past. Moreover, whereas the investment in vehicles can be varied as opportunity allows, the investment in track is fixed, and the land and works involved can rarely have an alternative use.

And so my third main point is that the primary division of all our studies must be, not road and rail, but between Carrying and Track.

Now if we regard Track as comprising permanent way or road, and if we include signalling in it, the term Carrying must cover the rest. The basic elements in the cost of each species of carrying-vehicle in our service—train, bus, heavy lorry, small van and private car aforementioned—are then reducible to (*a*) manpower requirements, (*b*) fuel requirements, (*c*) provision and maintenance of rolling stock. By far the most important item in the social bill for Carrying is manpower. We may therefore derive comfort from the fact that manpower is one of the 'safest' items in the economic computation of carrying cost.

Taking the three heads together, and notwithstanding a complicated interplay of the many factors and circumstances, and some highly technical considerations also, it is possible to show that the several species have their distinct and measurable characteristics of *carrying* cost, and their own potentials.

4. Suspect Calculations of 'Benefit'

So the processes of measuring on the cost side of the account have their possibilities, but what about the benefits side? How do we arrive at the credit for the 'social benefit'—the benefit to society—offered by each service or type of service?

A measure frequently used of recent years in calculating the return from road construction is to add up, in terms of time saved, fuel saved and so forth, all the different benefits conferred upon all the individuals expected to use the new facility. Admittedly a commercial concern does not evaluate its investment programmes in this way; it credits only the benefits and profits to be derived by itself, and does not include those accruing to its customers; if it did, an astronomical return would often be shown. Even the modernisation of British Railways would show a magnificent profit on such a basis. For example, if the track and signalling improvements produced a saving of only ten minutes (valued at a shilling) on each of the 1000 million passenger journeys a year, this would mean some £50m. of 'social benefit' to be added to the return on the investment.

And following the same line of thought, what should be credited to the regular public services on account of the time and trouble which the community would otherwise expend on making its detailed arrangements for each journey or transit, plus the 'loss' occasioned because many of the journeys or transits would not eventuate at all, and plus the higher cost of many that would? A simple calculation shows that several hundred million pounds a year would hardly cover society's loss if these regular public services were withdrawn.

But let me not add to the suspect calculations already in circulation. My intention is merely to show the need for caution in dealing with computations of 'social benefits'. And this is my fourth main point, coupled with the thought that High Policy must take account of many considerations which one cannot express in figures at all—e.g. the social value of population dispersal and so forth.

5. 'Carrying' Potentials

Concentrating, therefore, on the comparative social costs of making various forms of carrying capacity available, rather than on subjective and speculative assessment of their largely imponderable benefits, I come to my fifth point, namely, that any exclusive claim by any one type of carrier to an innate superiority for all purposes in all places is nonsense. It depends on the circumstances of employment. Even the private car can prove socially economical in suitable cases.

The significant thing is that the *ranges* of performance and cost of each carrier are considerable, and often overlap each other. This does not mean that the natural characteristics and 'bests' of the different carriers are not clearly distinguishable. For example, under the important head of carrying manpower, train performances like 10,000,000 seat-miles a year per man of train crew, or 12,000,000 capacity ton-miles, are far beyond the powers of buses and lorries, and this advantage remains even after the manpower needed for train marshalling, shunting and so forth is taken into account. On the other hand there are plenty of circumstances in which both bus and heavy lorry will use *less* carrying manpower than the train.

6. Economy of Combined Carrying

It follows that the total social cost will be lowest when the various types of carriers are used in combination. Their potentials are there to be properly exploited, singly and together, both in their appropriate places in the general scheme of things and *jointly* in individual journeys or transits. The difficulty is that they do not associate very willingly or naturally. However, society might well wish to insist on a certain amount of combined working where appropriate: might seek to avoid discouraging those public services (both road and rail) which are economical carriers and, in addition, economical users of track as we shall see; and should aim at the intelligent utilisation of all the community's transport apparatus as a whole, including the private car.

This is my sixth point. If instead of deliberately intensifying the separateness and hostility of the rival camps, road and rail, we had learned to use them in conjunction, we would have saved ourselves the cost of millions of road-vehicle-miles over arterial stretches where the vehicles (or their containers) could be cheaply 'entrained' for this purpose, and achieved a big reduction in congestion on the roads and a profitable employment of the rail track.

7. Distortion caused by 'Track' Cost

No doubt this is all very obvious. But why, then, is the pattern of public demand developing along lines so different? There are many interesting answers, and here it must suffice to mention only two of them. First, the individual has always been aware of his private interests, naturally enough, whereas all the individuals together, collectively, are only now being forced by circumstances to think about their collective interest as society. But secondly there are the concealing and distorting effects of public regulation, and of public policy in relation to matters of Track.

On this question of Track I propose to enlarge a little. Not only is its potential cost to the community very great; not only are the economics of carrying gravely distorted by the incidence of track cost, which is a particular burden on some of the public carriers; but also we are presented with a vital problem of logistics. Track is at once the most speculative, elastic and arbitrary element of transport cost. At the same time, like public regulation, it can be one of the main keys to social policy. This is my seventh point.

8. Erroneous Assumptions about Track Cost

Let us begin by looking at three major misconceptions which bedevil the subject of track cost:

(*a*) It is *not* true that rail carriers are favourably treated in that they pay no fuel duty; they pay instead the actual upkeep and a heavy charge for interest on the track (totalling about £120m. a year); what the chief carriers actually pay for track—rail, bus and heavy lorry—is illustrated by the following table:

	Road	*Rail*
Miles of route	190,000	19,000
Paid per route mile	£2000 (tax)	£6000 (cost)
Paid per passenger-mile (heavy carrier)	0·2*d.**	0·7*d.*
Paid per ton-mile (heavy carrier)	0·3*d.**	0·5*d.*
Paid per unit of fuel consumed	2*s.* 6*d.*	6*s.* 6*d.*
Proportion of Track Cost to Total Cost	Seventh or tenth	Fourth or fifth

* Plus a small element for vehicle duty.

The five million private cars and small delivery vehicles make a greater relative contribution than the bus and heavy lorry because of purchase tax and because their fuel consumption is high in relation to their carrying capacity. But it is the bus and heavy lorry which specially compete with the train, and though their tracks are often different in quality and in their potential for disciplined throughput, the rail carriers would be some £70m. a year better off if, like the road carrier, their track were paid for by the community in return for a tax on power at half-a-crown a gallon on diesel oil (and the equivalent rate on coal or electricity);

(*b*) it is *not* true, or certainly not provable, that the country makes a 'profit' out of the fuel tax and vehicle duty; these amount to £400m. a year, and calculations can be produced to show that the true cost to society of providing these rights-of-way might well be much greater;

(*c*) however, it is *not* possible to arrive at secure or satisfactory measurements of the cost to society of the existing networks, road or rail, either in total or in detail sector by sector of main route, feeder and terminal facility, public streets and so forth.

If all this—my eighth point—seems a little surprising in view of the propaganda we hear, and the allegedly exact figures that are bandied about, I can only reiterate that what I have said is correct.

9. 'Track' a Matter of Taxation

Apart from the sheer impossibility of ascribing appropriate fractions of total track cost (itself unknown) to thousands of different operators in a myriad different circumstances of transit, there are obviously other reasons why the amounts to be paid for the use of track—better called right-of-way perhaps—are not something which can be left for determination to the ordinary economic forces of cost or market price. Subject to a few special cases like tunnels, bridges, etc., we must content ourselves with the inevitable, namely, that any charges or 'tolls' levied must be akin to exercises in taxation. And like taxation, any scheme of tolls in force can, and should, reflect considerations of wider social policy.

This, I think, is my ninth point but it does not mean that the economics do not matter. They matter a great deal. Space for track is in short supply at the critical points; nor is the public purse without a bottom. What charge ought to be made by society—the tolls, as it were—for the use of track? There is no dearth of theories, but one which goes to the heart of the problem is that tolls or taxes for right-of-way ought to rest on bases which will procure the most discriminating use of road and rail, according to the varying situations of time and place. Congestions and peaks are normally both brief and local. Special licences, then, for city centres? Costly carnets for particular hours and days or routes? Should the slow vehicle pay more than the fast—or vice versa? Who gets in whose way? Obviously a detailed and comprehensive application of the theory will bristle with difficulties. I doubt whether one would get far with it in practice, though there are some limited applications which would be feasible and helpful.

10. Misconceived Figuring of 'Return'

But we are interested in the charge for new facilities as well as for existing facilities. The great drawback of the 'community' nature of track cost is, of course, that the standard test of any new facility—will it pay?—is not available. How do we resist the great pressures of uneconomic demands when they cost the demander nothing, at any rate directly and *pro rata*? Or how do we settle our priorities among the works proposed?

It is often suggested that 'rate-of-return' tests can fill the void. Let us calculate the benefit to

society from a given work in relation to its cost, and assign it priority according to the rate shown! Unfortunately there are serious dangers in this all-too-simple idea. The figuring is invested with a precision and decisiveness which it cannot possess, if only because the benefits are too notional or imponderable. Either the result will be wishful figuring, since the calculations cannot be checked back in real life (i.e. the essential accountability is missing); or if the figuring is painstakingly honest and ignores everything but 'likely and measurable fact', many a first-class scheme will be killed. Of this latter process there are plenty of examples in railway history since 1921.

My tenth point, then, is that the all-essential vision cannot be built into calculated 'rates of return', scheme by scheme, and though such calculations have their domestic uses, they cannot serve as automatic tests or regulators of investment proposals.

11. Width and Length of 'Track' Planning

In the ultimate (my eleventh point) the planning of the nation's system of circulation, its veins and arteries, must be based on a much wider approach.

We must reckon in wholes and not in parts. The consequentials or repercussions of particular schemes must be reckoned in. For example, what are the effects on terminal areas of improving the main-line flows? Or will new bottlenecks emerge when old ones are removed?

And the imponderables must be considered. Safety, amenity, distribution of industry and population, availability of social resources (not to mention cash), strategic requirements, housing and so forth. The needs of town planning, indeed, are almost a basic part of the problem.

An American economist has even suggested that really large and closely-built city centres would find it cheaper to offer free public transport rather than undertake the enormous costs involved in trying to accommodate private transport. However that may be, it is not difficult to perceive that the high cost of a new railway underground in London ought to receive a credit, in any social accounting, for the relief it brings to road transport on the surface.

The mutual effects of road and rail upon each other might well enter into our calculations on a rather more general scale. Both physically and financially the two forms of right-of-way are often an indivisible problem. The closing or opening of one can make an immediate difference to the other. This is not to argue that a road, or in particular a railway, ought to be automatically protected against a lusty newcomer, or that unused or abandoned transport facilities are necessarily a sign of waste. But a combined view of both road and rail rights-of-way should be taken.

12. Equalising Track Finance

Meantime, however, when testing the economics of capital expenditure, we apply one set of criteria to road projects and another to the railways. On new roads we calculate the 'social benefit', as already described, whereas railway modernisation is tested by whether it will balance the accounts of the railways, leaving all social benefit out of the reckoning.

Why is this? Simply because the railways are statutorily bound to a commercial measurement of profit and loss, whereas the normal play of 'financial' forces cannot, in the nature of things, be the guiding principle for investment in roads? If this is the answer, it is a poor excuse.

Meantime, also, road and rail still have their differing bases and structures of track cost, with decisive inequalities in the track burdens of public road carriers and rail carriers, passenger and freight, as a result. And so we find ourselves faced once more with the old suggestion that the track cost of railways ought to be treated more like the track cost of roads. In other words, the railways would pay a toll, and provision of the track would be defrayed out of public expenditure.

But how much the toll should be, is a matter of social policy. So are a great many other things in the world of transport track, however, and indeed in transport generally. The important thing is that the policy shall be clear, and based on a more scientific understanding of the social costs and social benefits involved. The need to reconsider track finance is my twelfth point.

13. Old Myths and New Delusions

We need, also, to begin by getting rid of some of the old myths and new delusions—my thirteenth point.

It no longer serves any purpose to insist on civil war between the public carriers on road and rail.

Nor is it sensible to indulge in nostalgic hopes that the free forces of competition can be left to solve everything—or *per contra* that nationalisation would make superfluous our further economic studies. Nor is it necessary to fall back on great schemes of subsidy, which is a solution born of unnecessary despair (or ineptness). And the importance of discipline, fiscal or physical, in improving the 'throughputs' of traffic must be realised. All these things need to be learned. The cynics allege, of course, that we shall learn only by bitter experience after things have become almost impossible.

14. The Engineer-Economist

There are suggestions that impartial agencies such as Road/Rail Boards should be set up to study the problems involved, but whatever happens in that respect it will remain true that engineers and economists will have a special responsibility for future developments.

This is my fourteenth and final point.

Engineers and economists are complementary; if the engineer tends to think along 'heroic' lines the economist is more inclined to be 'prudent'. In the balance between the two will lie the right approach, and whereas ultimate policy on the Road/Rail Question is more a matter of art than science, there will be no wise policy which is not based on a scientific approach to the facts, and here a great deal of work is waiting to be done.

My own guess is that the intelligent handling of the Road/Rail Question will save society some tens of millions of pounds a month, if not more, and an infinity of frustration.

THE EVOLUTIONARY SIGNIFICANCE OF HUMAN HAIR PATTERNS AND SKIN COLOURING

By Dr. C. B. GOODHART *University Museum of Zoology, Cambridge*

In this talk I want to try to look at the human body, and at human behaviour, through the eyes of a zoologist, to see what we can learn of our evolutionary origins and relationships from a study of the natural history of Man as a living animal species, rather than from his palaeontology. This sort of approach is bound to be speculative, but it was the one followed by Charles Darwin himself in laying the foundations of Physical Anthropology. Indeed, he once wrote: 'I am a firm believer that without speculation there is no good and original observation'.[1]

Hair Distribution

Although our bodies are largely hairless, where there is any hair left it is often long and dense, and not at all vestigial. It has its characteristically patchy distribution because, although nearly all of the originally continuous warm furry coat of our ape-like ancestors has been lost, the so-called 'sematic' hair tufts, whose function was epigamic adornment rather than keeping the body warm, have been fully retained. Many adult male monkeys have beards and moustaches, or manes on the head and shoulders, of this epigamic hair and it makes them look large and fierce, and is used in the threat display during sexual fighting. As that is usually a matter of bluff and bluster, with little blood actually shed, a ferocious appearance has selective advantage in evolution, for rival males are frightened off and prevented from fathering the next generation. It is an interesting and important observation that, despite the loss of our body fur, some living races of mankind can still show as luxuriant a display of typical epigamic hair as any of the other primates. This surely should be relevant in any discussion of human evolutionary origins and behaviour.

There can be no doubt that the beard is an epigamic adornment, in men as in monkeys, since it grows only in the male at sexual maturity. And much of the rest of the long, coarse and conspicuous hair which develops fully only in adult males is likely to have had the same origin: it cannot represent a remnant of the warm fur for, if it did, women and especially children should have it too as they are smaller and more susceptible to cold. The hair of an adult man is all seen to best advantage from in front as he stands up to attack, and if this were the skin of an ape in a museum it would be easy for a zoologist to reconstruct its threat display. We can picture our remote ancestor as he stands defiant on his hind legs, a mane of shaggy hair reaching to his shoulders, with beard bristling and glaring eyes accentuated by the arched eyebrows above and curling moustaches below, and with bare cheeks and forehead flushed in anger. As he lifts up his head to utter deep roars of rage the bushy hair on the chest beneath the beard is exposed, below this the pubic hair extends up to his navel, and he beats his breast with hairy fists and forearms. Even today soldiers adorn themselves with hair and feathers to exaggerate their own natural sematic hair patterns; the bearskin of the guardsman, the Highlander's sporran and the field-marshal's plumes are familiar examples.

The different races of Man show a well-marked polytypism in the amount, distribution, texture and colour of their epigamic hair, just like the geographical sub-species of some monkeys. Europeans are among the hairiest of all peoples, and they include different regional types with blond, brown and black hair, curly or straight, and with a polymorphism for conspicuously red hair; but most other races are a good deal less hairy, and the beard is often reduced or absent. That, however, cannot represent the earlier stages of beard evolution, which must have occurred by lengthening the ordinary body fur before the characteristically

human nakedness had appeared. So we must conclude that races still well-provided with hair and beards are more primitive in that respect, and closer to the ancestral sub-human stock, than the majority in which they have become reduced. It is significant that savage warriors of the less hairy races often seek to supplement their own scanty epigamic hair by decorating themselves with monkey skins, ostrich feathers or lions' manes, evolved as epigamic adornments for their original possessors.

Darwin[2] recognised the sexual significance of beards and other epigamic structures in the male, but he believed that they had evolved in response to 'sexual selection', by the females choosing the handsomest males as mates. Actually it does not usually happen like this, if only because the females seldom have much choice in the matter, though of course in the end they do get the largest and most impressive males, who are able to frighten the others away. Darwin also thought that sexual selection had been operating on the female. He observed that although men of even the hairiest races can seldom grow their head hair below the shoulders, in the women it commonly reaches well below the waist and is fine and silky, and regarded as a sexual ornament; he may have been right here in suggesting that this was due to men deliberately choosing wives with the finest hair. And he regarded human hairlessness as an epigamic character, evolved in response to selection by our ancestors, who liked their women with naked bodies, as well as with a fine head of hair; and nakedness, evolved by the female in response to sexual selection, had then become assimilated to the male in the absence of any contrary selection for body fur, although the male epigamic hair was retained. In no living race do young adult women ever normally have hair on the face, nor on the chest nor immediately below the navel, and this deficiency is actively maintained by the hormone balance of the female body. When it is upset pathologically, or at the conclusion of the child-bearing period, hair often does begin to grow on the chin and upper lip. But, although women do not mind hairy men, they seek to remove all superfluous hair from their own bodies, for sexual selection still operates against female hairiness and a girl who has even a trace of a beard or a moustache will have difficulty in finding a husband.

There is lastly the puzzling problem of the pubic and axillary hair tufts, which appear only after puberty and look like typical sematic hair, but are equally well grown in both the sexes. This curious and rather insanitary arrangement seems to be unique to Man, for in most mammals these parts have less, rather than more, hair than the rest of the body. It has been suggested[3] that at one time the baby may have hung on to his mother's axillary tufts as she swang from branch to branch—did her pubic hair provide him with a convenient toe-hold? But this seems an awkward arrangement, and anyway it would only work in a tree-living creature moving by brachiation with uplifted arms, and it is now thought that Man is descended from the bipedal ground-living australopithecines.

Hingston[4] on the other hand, thought that these tufts were part of the epigamic threat display of the adult male, and he pointed out that they are concealed as a man crouches down and shown when he springs up with arms raised to attack. There may be some truth in this picture, particularly in explaining the convex upper boundary of the pubic hair in a man, which gives him a conspicuous hairy patch on the belly, compared with the concave arrangement in women. But it does not explain why women have any pubic hair at all, nor hair in the armpits as well grown as a man's, for the female does not engage in sexual fighting and women do not have the beard and other epigamic adornments of the male.

There may, however, be another and quite a different explanation for the pubic and axillary hair. Specialised scent glands are found in these parts, called 'apocrine' glands and derived from the temperature-controlling 'eccrine' glands, which are distributed all over the body and secrete a dilute odourless sweat. The apocrine glands occur in the armpits and around the genitalia, and are not thermoregulatory but are responsible for the characteristic body odour, produced by both sexes after puberty, principally in circumstances of emotional stress. The secretion is at first odourless, but a smell soon develops on exposure to the air, probably as a result of bacterial fermentation.[5] The apocrine glands seem to be specialised for the production of this scent, it is not a by-product of some other physiological process, and that suggests that it must once have had some functional significance. Mammals often produce specific scents, usually of sexual significance, as in a billy-goat or a bitch on heat, though they may also serve to keep a gregarious

herd together, or for marking territory. Among the primates, scent glands of uncertain function have been found in lorises,[6] marmosets[7] and spider monkeys,[8] and gorillas in the wild are said to smell of 'a mixture of human sweat, manure and charred wood'.[9] It is not easy to suggest what may have been the function of the apocrine scent in primeval Man but, if it was of some significance, the tufts of hair associated with the glands which produce it would be well adapted to provide a surface for the oxidative reaction, and to facilitate its dispersion in the air. And it is interesting that the amount and quality of the apocrine scent is different in different races. Europeans, even those who wash, are said to have a disagreeable smell to the Chinese, who to us are relatively odourless, while the Bantu, whom we consider to have a quite distinctive scent, claim to be able to smell a white man a mile away. So the different geographical races of Man are showing the same sort of polytypic variation for scent as they do for hair and many other characteristics.

Skin Colour in Primates

Unlike most mammals, the primates have full colour vision and so colour plays an important part in their sematic adornment; some monkeys, like the guenons, rival birds with their fur colours, and the bare skin of the face, buttocks and genitalia is often vividly coloured with melanoid and porphyrin pigments, as in the Mandrill. Apart from the florid noses and cheeks of some elderly white men, which are pathological, Man does not go in for such permanent sematic skin colouring, although some savages may ape the Mandrill with their war paint; as Goethe[10] has observed: 'Bemalung und Punktierung der Körper ist eine Rückkehr zur Tierheit'.

Monkeys, like men, become flushed in anger, and Darwin[11] has described how he was teasing a rhesus monkey at the Zoo whose 'face reddened as plainly as that of a man in a violent passion . . . at the same time, the naked posterior part of the body, which is always red, seemed to grow redder'. The Red Uakari Monkey, *Cacajao rubicundus* (Geoffroy), is another good example, with its whole head naked and flushing bright scarlet when annoyed. An angry man, too, goes red in the face, the upper part of which is naked over even the heaviest beard, and the threatening flush turns pale with fear in defeat; it must surely once have formed part of our epigamic threat display, as it does now in apes. Even the genetic baldness, which afflicts some men in the prime of life, might possibly have had some significance here. For the beard, and the rest of the hair, is not affected, and a bald pate, flushed with rage, would be a frightening sight, all the more so for its comparative rarity. Such an explanation for a polymorphism involving a bald patch flushing red on the head of an adult male ape could not be dismissed as absurd.

There is a good picture of sexual fighting and threat in primitive man in the *Iliad*.[12] Paris, clad in his panther skin and long-plumed helmet, brandishing a couple of spears, advances towards the κομόωντες Ἀχαιοί, δεινὸν δερκόμενοι, 'the long-haired Achaeans, glaring terribly'. Then ξανθὸς, βοὴν ἀγαθὸς Μενέλαος 'golden-haired Menelaus, good at the war-cry' rises in his wrath to overawe Paris and ὑπό τε τρόμος ἔλλαβε γυῖα, ἂψ δ' ἀνεχώρησεν, ὤχρός τέ μιν εἷλε παρειάς, 'trembling seized his limbs beneath him, he drew back, and pallor laid hold of his cheeks'. This is just what happens in a baboon colony when a young bachelor has seduced one of the overlord's consorts and is challenged to a fight, only to retire abashed by the threat display of his rival.

Lewis[13] has discussed the nervous control of flushing and pallor in Man. The skin of the face is innervated from the cervical sympathetic chain, which maintains muscle tone in the capillary walls, with an antagonistic parasympathetic supply to produce dilatation. Flushing appears to be due to the inhibition of the sympathetic fibres and pallor results from their stimulation; flushing and pallor often alternate in quick succession, which enhances the visual effect. The mechanism is evidently a complex one and it appears to serve no other purpose than to provide an external sign of anger, embarrassment or fear, so it is not unreasonable to look for some explanation of its evolutionary origin in the behaviour of our pre-human ancestors. Many apes have just the same mechanism, and with the skin of the buttocks innervated from the sacral outflow, and in them it certainly is adapted to an epigamic function.

Emotional flushing in Man is normally restricted to the face and neck and it does not appear in the orbits nor around the mouth; this may serve to accentuate the redness of the lips and, like the arched eyebrows, to emphasise the eyes, especially as they blink under stress of emotion. There are

several examples of this in monkeys: *Trachypithecus obscurus* (Reid) has a black face with short white fur in the large orbits giving flashes of white as the eyes open and shut, the mangabeys have white eyelids exposed as they blink, and the male Gelada Baboon has blood-red eyelids used in his highly dramatic threat display.[14] These are the so-called 'dymantic' patterns of display, those which have a startling effect, and another is shown by male baboons, mangabeys and other apes who, when threatening, suddenly lift up their heads and thrust out large pink tongues at their rivals. It is interesting to reflect that rude little boys sticking out their tongues as a gesture of defiance may be showing the last vestiges of what was once an important part of the threat display of their adult forefathers. Homer admittedly does not record that his heroes stuck out their tongues at each other before the fray, but perhaps the laugh of scorn at an enemy's discomfiture may have had the same origin. It may be significant that in Maori war dances the tongue is frequently thrust out, and Maori carvings often depict warriors and demi-gods making this gesture.

Blushing

According to Darwin[11]: 'Blushing is the most peculiar and the most human of all expressions. Monkeys redden from passion, but it would require an overwhelming amount of evidence to make us believe that any animal could blush.' But men, no less than monkeys, 'redden from passion', and it is only the blush of shame which is so peculiarly human, and that is physiologically indistinguishable from the flush of anger. Perhaps Darwin only meant that he could not believe that any animal could feel the shame that produces a blush; as Mark Twain put it: 'Man is the only animal that blushes —or needs to.'

Both the sexes blush, especially girls exposed to sexual embarrassment, and although shyness or guilt, without any overt sexual content, cause it too, Freud might have seen some connection there as well. That women blush at all suggests that its epigamic function may not have been confined to the threat display of the adult male. But, although Darwin considered the possibility that it might have served to make women more attractive to men, just as he believed that long silky hair and a naked body had evolved in response to sexual selection, he concluded that 'the firmest believer in the efficacy of sexual selection will hardly suppose that blushing was acquired as a sexual ornament'; but it may be worth looking into this matter again. Darwin himself observed that 'a pretty girl blushes when a man gazes intently at her, though she may know perfectly well that he is not depreciating her.' He goes on to quote Burgess, bowdlerising slightly, who wrote[15]:

> The Circassian women, who are so celebrated for their beauty, and so sought after by the keepers of the seraglios of Persia and Turkey, although not perfectly civilised, are occasionally seen to blush deeply, according to Lady M. Wortley Montague's account.
>
> It is even considered an acquisition by the Sultan, as giving proof of their not being ultra barbarous, and those females who are thus capable of exhibiting their internal emotions, invariably bring a higher price than their less susceptible sisterhood.

Burgess goes on:

> It may, indeed, be very interesting to see a young lady in a drawing room blushing for some trivial cause, as the blush invariably heightens the charms of beauty; and as it is, in this instance, considered to be a test of purity and innocence, many fond parents will, perhaps, coincide with the Sultan's ideas respecting fair Circassians, and think it rather an acquisition than otherwise in their daughters; but I am of opinion that a blush is no test whatever of either purity or innocence, for many libertines and prostitutes may be seen to blush as deeply as individuals of the most exalted purity and virtue.

So there *is* some evidence that blushing occurs during courtship, and is seen as a sexual ornament in the eyes of men, and it is not necessarily provoked only by anger. A maiden's blushes when her modesty is outraged by the demands of a would-be lover do not always indicate that she hopes he will desist, nor do they usually tend to discourage his ardour. In Darwin's own words, 'no happy pair of young lovers . . . probably ever courted each other without many a blush' and, apart from the impropriety of the idea, it is not easy to see why he was so sure that blushing could not have evolved in response to sexual selection. There are few records of female apes flushing during courtship, but it might be worth looking for, as Zuckerman[16] did see the sexual skin of a chimpanzee colouring at the approach of a male, just like the cheeks of Darwin's young lady in a similar situation.

Sexual Skin

Most adult female old-world monkeys have bare patches of skin, especially around the genitalia, highly vascularised and with massive deposits of hyaluronic acid, which show striking changes in colour and tumescence during the menstrual cycle. This is called the 'sexual skin' and it has been defined[17] as any skin which responds to oestrogenic stimulation by colouring or swelling. The vividly coloured epigamic skin of certain male monkeys comes within this definition, as it responds in the same way to the artificial administration of oestrogens.

Darwin believed that the female's sexual skin had evolved as a result of sexual selection by males, but Zuckerman[18] rejects this interpretation and thinks that its biological significance is in ensuring that mating is synchronised with ovulation. A female baboon is at her brightest when the follicular hormone is active just before ovulation, and a polygynous male always goes with the most conspicuous of his consorts. But this does not really contradict Darwin for, if the males choose the most decorative females, a selective advantage will attach to ever larger and more vivid areas of sexual skin, and so it seems that this could be one of the few examples left of the effects of sexual selection in Darwin's original sense. Another theory[19] is that the hyaluronic acid may be a barrier against the penetration of infective agents, but that can hardly be its primary function as the sexual skin usually covers only a smallish part of the body. Its firm and resilient texture may, of course, serve to protect these areas from bites and other injuries inflicted during courtship.

Man is one of the very few old-world anthropoids without any sexual skin in the female, unless indeed the brown pigmentation of the perineal region, developing at puberty, represents the last traces of it. Cuvier thought that the macronympha and steatopygy of bushman women might be homologous with the sexual skin of baboons but that is not so, though they may possibly be epigamic and evolved by sexual selection[20]; even in Europe feminine callipygy is sufficiently admired for the Greeks to have had a word for it. And it can even be suggested that the areolae round the nipples could perhaps have had an epigamic function, though they do not have the characters of sexual skin as strictly defined. But they are a conspicuous feature in adult women, formed of highly vascular, pigmented and erogenically sensitive skin, and having considerable sexual significance, in addition to any possible function in suckling. The feminine breast is certainly of sexual interest to men; ethologists might class it as a 'releaser' of courtship behaviour and, like many releasers, it has little direct connection with the functions subserved by the pattern of behaviour released. And it is significant that the nipple with its areola is one of the few parts of the body that a European woman may still not expose in public. It is not the shape of the breast that matters, and a lot of its surface skin could properly be shown even in Victorian times, but the areola, and not much else, is still the irreducible minimum to be concealed. Such a structure serving such a function in an ape would surely be considered of epigamic significance, and there is perhaps an example in the so-called 'bleeding heart', a red patch of sexual skin, between the breasts of the female Gelada Baboon,[21] which doubtless has its part to play as a releaser of male courtship behaviour.

Kissing

The red exposed surfaces of the lips, too, seem to have some epigamic function in Man, though they cannot be classed as sexual skin. But they are erogenously sensitive, sexually attractive, brightly coloured with the colour sometimes artificially accentuated, and used in the quite well-defined courtship pattern of kissing. It is interesting that until recently a Moslem woman might not show her lips to a man, just as the areola must remain covered in Europe, and in Japan a kiss on the lips in public was treated as an offence against decency. Apes do not kiss, but several species have a lip-smacking action in courtship which may represent a stage in the evolution of the human kiss. Thus the female howler monkey[22] will solicit a male by forming 'an oval opening with her lips, and her protruding tongue will rapidly oscillate in and out and up and down . . . this gesture is symbolic of sexual desire . . . and it stimulates appropriate responses in a male'. And Bolwig[23] has recently described lip-smacking in the baboon: 'the lips are moved, rapidly exposing and covering the teeth in a quick succession, while the tongue is moved in and out. These movements produce an audible smacking sound . . . it is a friendly gesture, probably with a sexual background. It precedes copulation and lasts

throughout the act.' If the lips were soft and protruding and highly coloured, as they are in Man, they might well be regarded as epigamic structures adapted to courtship behaviour.

Conclusions

This discussion has necessarily been rather speculative but, for what they are worth, certain conclusions can be drawn from it.

Firstly, the ancestral human stock must have resembled the modern European races, and also the Australians and Ainu, in having long shaggy head hair and beards more closely that the relatively hairless peoples now usually living in the tropics. The Negroes, and other races with scanty beards or shorter hair, must be descended from hairier forms since the typically human pattern of hair distribution, common to all races, must have evolved out of a generalised body fur before our sub-human ancestors had acquired their characteristic nakedness. A sparse beard on a naked body can only represent the loss of a full beard, not an early stage in its evolution.

Secondly, the ancestral human type must not only have been hairy, but also light-skinned. That is rather a surprising conclusion, but it is derived from the argument that a flush can only be seen under a fair skin although it occurs invisibly in all the darker races as well. If the complex mechanism responsible for flushing and blushing did once have an epigamic function in Man, as it certainly does in some apes, then it will only work with an unpigmented skin. Darwin knew that Negroes blushed invisibly, and he considered that a decisive argument against its having any functional significance; but all it really shows is that blushing can have no sematic significance in the dark-skinned peoples. However, this could as well indicate that the skin pigmentation had been secondarily acquired, as that facial flushing in Man, though not in light-skinned monkeys, is without any evolutionary or functional significance. And, of course, the red colour of the lips and areolae, for which an epigamic function has been suggested, is only really conspicuous on a fair skin.

Dark skins have probably been acquired independently by several different racial stocks as an adaptation to life in the tropics, for which an unpigmented skin seems to be ill-suited. So that if the original human type was light-skinned it is likely to have been evolved in temperate latitudes. An objection may be raised here, which needs an answer. All living fair-skinned peoples come from the cold temperate regions, which certainly do not provide the optimum climatic conditions for human life. We can live here only by maintaining a sub-tropical microclimate around our bodies with clothing, and so it has been argued[24] that primeval Man must have been a tropical creature and, if he was, would he not have been as dark as all the various races now living within the tropics? However, it must be remembered that climates change and the temperate latitudes were a good deal warmer in the Pliocene, and much of the Pleistocene, than they are now. When hippopotamuses and hyenas lived in London[25] it may well have been warm enough for a man without clothes, and yet the latitude was the same so that the sun rose no higher and was probably no stronger, than it is today when Londoners do not suffer unduly from having fair skins. So our fair-skinned ancestor, with his naked body and well-grown epigamic hair and beard, probably *could* have found a congenial climate in temperate latitudes, not necessarily in Europe of course. When it grew colder his descendants had the choice either of adopting clothing, when they could remain physically much the same, or else of migrating down into the tropics, where they could live unclothed, but lost much of their epigamic hair and evolved pigmentation as an adaptation to the stronger tropical sun.

Finally, there are some conclusions about the social and sexual organisation of primeval Man and his pre-human progenitors. Many of the non-human primates live together in more or less stable bands or family groups, which show several different types of social and sexual integration.[22] In the gibbons, males and females are similar in size and appearance, of equal dominance status, and live together as monogamous families with their juvenile offspring, who are excluded as they reach maturity. Spider monkeys and howlers form larger groups having a 'socionomic' sex ratio of about twice as many adult females as males, with the surplus males living apart. In these heterosexual groups the dominance gradient is low, with little intragroup fighting, and receptive females are shared by all the males. In macaques the socionomic index is lower, with half a dozen females to each adult male in the group, and there is considerable fighting to establish

dominance, and well-marked sexual dimorphism. Mating, however, is promiscuous and individual males do not maintain harems for their own exclusive use. But baboons[26] do have harems, which are jealously preserved, and the females are very subordinate and not at all promiscuous, adultery being viciously punished. The males are much larger than the females, and sexual motivation is strong so that they are constantly threatening and challenging their rivals. As a consequence, formidable manes and other epigamic adornments have been evolved in the male. All these forms of mateship occur in different human cultures, but our sexual dimorphism in size and strength, and the well-developed epigamic hair, beard, voice and skin-flushing mechanism of the male would seem to indicate that the original sub-human form of social organisation resembled that of the baboons more closely than those of most other living primates. When there is strong sexual motivation, with dominant polygamous males, conditions are most favourable for the evolution of male epigamic characters, and men of certain races, even today, can show a more impressive display than most monkeys, comparing not unfavourably even with the baboons in this respect.

Furthermore, the baboon way of life is pre-adapted for the adoption of carnivorous and hunting habits, which must have been the next step in sub-human evolution, unique among the primates. As a result of intra-specific sexual competition, male baboons have become large and fierce and although they are, in fact, not usually carnivorous they could quite easily become so, especially if they combined to hunt in packs like wolves, when they should be able to kill quite large animals for food. This may have occurred at the australopithecine stage, and the need for the males to abandon some of their sexual rivalry in order to hunt together, and to share out the kill, may have represented the first signs of a truly human co-operative type of social organisation.

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CHALLENGES TO AGRICULTURAL RESEARCH

By Sir WILLIAM SLATER, K.B.E., F.R.S. *Secretary, Agricultural Research Council*

British agriculture is made up of a wide range of enterprises differing markedly in size and character from the small intensive market garden to the large extensive hill farm. Each individual enterprise has its own peculiar characteristics of soil and climate; no two, however similar they may at first sight appear, are entirely alike.

The problems which arise are equally diverse. Every farmer has his own special difficulties which, should he be asked, he will maintain have a prior claim on the available scientific manpower and resources. Many of the problems which worry the farmer require for their solution only the application of existing knowledge to the particular conditions on his farm; such problems lie in the province of the advisory officer. With others the existing knowledge, although available, cannot be applied immediately; it must, before it is recommended to the farmer, be tried out in practice under controlled conditions. The responsibility for conducting field trials of this kind again falls on the advisory services and is one of the main functions of the Experimental Husbandry Farms and Experimental Horticultural Stations in England and Wales, and of the College Farms, to which the advisory officers are attached in Scotland. Many trials are also carried out on commercial holdings by advisory officers working in collaboration with farmers.

A third set of problems remains, the knowledge for the solution of which is not available. These represent the challenges to research.

Although the problems arising on each farm are characteristic of that farm, when the many individual questions asked by farmers are considered as a whole a general pattern emerges. From this pattern it is possible to pick out the major problems, that is those which in broad outline are common to a large number of farms.

When the importance of a practical problem has been agreed, it is rarely presented in a form which can be put directly to the individual scientist for solution. Almost every practical problem consists of a complex of scientific problems, and the first step is to identify these. This in itself is often a difficult task, calling for research ability of a high order. When the practical problem has been broken down into its scientific components, it may prove that much of the knowledge required to answer the individual questions is already available. For the rest scientists must be set the task of filling in the gaps.

The knowledge already available comes as a result of intelligent anticipation by the scientists. They must always try to fill the blanks in those sections of background information on which practical problems are most likely to call. The greater the store of this type of information, the greater the possibility of solving the practical problem quickly. Sometimes one or two relatively small gaps in our fundamental knowledge may hold up the solution of a practical problem. The task of filling them is often difficult; their very existence is an indication that they have proved hard to fill. The difficulty may arise from a lack of the men with the right training to undertake the work, or from the lack of ideas as to how the information can be obtained, or from a lack of facilities for carrying out the work. The lack of the right men is the most serious deficiency; if the men are available the ideas follow and the facilities can be provided.

When the scientific questions have been answered, they must be integrated to give a solution to the practical problem. This is not a simple additive process; the factors influencing the farming practice involved are interacting, variations in the one affecting the way in which the others react.

The synthesis therefore of the solutions to the individual scientific questions into an anwer to the original practical problem is a complex task. Moreover, failure to obtain one particular link in the chain may hold up the complete solution so long that it may be necessary to give the farmer a partial temporary solution, which at least gives him some help without providing the full and final answer. The time involved in solving some of the farmer's problems, which are costing him time and money, may make him impatient, but it is better to risk this than to give an answer based on insufficient information which may lead him into serious error.

The farmer is sometimes puzzled by the way the scientist sets about his task. The farming problem may appear to be one which is capable of solution by direct test in the field. Most farmers are vaguely familiar with the modern statistical layout of field experiments and the results obtained by its use. The short cut to the required answer may seem to lie in an experiment which simply tests under field conditions procedure A and procedure B, with sufficient randomisation and replication to eliminate the influence of the uncontrolled variables involved and to show whether there is a significant difference between the procedures. Such an experiment, if properly designed, will give a perfectly sound scientific answer for the comparison of the two procedures at the place and time of the experiment, but the result will not necessarily be applicable at another place or in another year with differing environmental conditions. Before farmers can be generally advised with certainty to adopt one or other procedure, such experiments must be repeated many times under as wide a range of conditions as possible. Such repetitions involve much work and may take many years; again, the final answer may well be that under some circumstances one procedure shows no advantage over the other, whilst under other circumstances there is a difference which the farmer will find economically worth while.

The scientist, realising these limitations, may decide that the better course is to study in detail the differences between the two procedures, isolating the factors involved and carrying out carefully controlled experiments—often in the laboratory. If he is successful in elucidating these differences the knowledge he has gained will enable an advisory officer to say which is the better procedure to adopt on any particular farm.

The challenges to agricultural research fall into three groups: one concerned with crop husbandry, another with animal husbandry, and a third with farm machinery and buildings. It is possible to deal here only with a few examples.

In both crop and animal husbandry there have been major scientific advances since the war. With the solution of one set of problems, however, a new group has arisen. In crop production the major advances have been the protection of the growing plant from pests and diseases and the chemical control of weed competition, with a resulting wider choice in crop rotation. There are still many pests and diseases which worry the farmer, but it is almost inevitable that these having so far resisted solution present the greatest difficulties to the scientist. In seeking methods of control he is being driven back step by step into fundamental studies of such subjects as the nature of inherited resistance to disease, host parasite relationship and the structure of the virus particle. Research of this kind calls for workers like the geneticist, the biochemist and the biophysicist—men who may have little knowledge of agriculture but without whose services these problems cannot be solved.

The increased use of chemical sprays for the control of insect and fungal pests has brought in its train a number of secondary problems. In the first place the farmer or fruit grower asks when he should apply the chemical control. This has created a need for careful studies of population dynamics and the relation of insect or fungal populations to weather conditions. By means of such studies it is hoped to give farmers increasingly accurate and timely information as to whether spraying is economically worth while or not, and if it is worth while, the time when it will be most effective.

If a spray is necessary then the farmer wants advice on how to apply it in the most economical way. He wants to use the highest effective concentration—to avoid cartage of water—which can be combined with a dispersal into droplets small enough, with right physical characteristics and sufficiently numerous, to give adequate cover on the leaves of the plants and yet not to be blown away in the wind. This work is a mixture of physics, engineering and physical chemistry, and

often involves investigations of a very fundamental kind.

Another way in which the farmers' needs have been met is to use systemic insecticides which are taken up by the plant and destroy the insects feeding on it. Some such insecticides are available but more are called for. Here there is need for the plant physiologist to study the movement of different molecular structures within the plant and of the organic chemist to provide materials which are at the same time translocated and toxic to insects. Fungicides with similar properties would be of great value and to supply them is one of the scientist's immediate aims.

There are two ways in which better insecticides and fungicides can be found; one is to examine the effect of all the available chemical compounds on different insects and fungi; the other is to study the physiology and biochemistry of insect and fungus in order to find the points in their metabolic processes which can most conveniently be attacked. The first method can best be undertaken by the large manufacturers of organic chemicals, the second is more suited to the research institute or the university.

Another group of questions asked by farmers relate to the use of fertilisers. How much fertiliser should be used at each break in a given rotation to obtain the maximum economic return? With the use of the new herbicides and the availability of new plant varieties, farmers have been working with rotations far removed from those traditional even up to the time of the war. The need to grow as much food as possible during the war encouraged a greatly increased use of fertilisers, a trend which has been maintained since the war, with guaranteed prices and markets. So far the good farmer has erred deliberately on the generous side in the use of fertilisers. If his land is clean and well worked and his variety right he has argued, rightly, that he would have to go a long way before he did not get back the value of his extra fertiliser. Now as he is perhaps settling into a more regular crop rotation, he is beginning to wonder whether the 'compound' he has got into the habit of using for a particular crop is always necessary. After years of heavy dressings he asks: 'Would it matter greatly if the phosphate part of the compound were omitted for a year or two?' This kind of question presents a formidable challenge to the scientist. We must know more about the soil-plant relationship, of the fate of plant nutrients added to the different soil types, their inter-reactions, the role of organic matter in maintaining soil structure and its effect on the availability of nutrients.

We can with our present knowledge give a farmer reasonable advice, but it depends too much on extrapolation from too few field experiments. We know that most farmers can still increase their use of fertilisers safely on many crops, but as more and more farmers push up their yields to new heights by the heavy use of fertilisers they will want much more precise advice from the advisory officer and he in turn will call for the knowledge which alone will enable him to give it.

Animal husbandry has three groups of problems: how to breed better stock, how to feed stock better, and how to maintain its health. We are beginning to doubt whether the art of animal breeding in which Britain has excelled, has not reached the limits of its possibilities. The breeder's 'eye' is gradually being replaced by objective measurements; measurements made possible by such developments as milk recording and artificial insemination. The farmer wants to know what he is to measure, how he is to make the measurements and, having made them, how they are to be applied to produce the animal he wants. The scientific problems involved are vast and intricate, but already the impact of the scientific method is being felt in the commercial breeding of poultry, dairy cattle and pigs.

The basis of the rations fed to our livestock is admittedly out of date. Just as with crops, so with animals; the higher the level of productivity the more precise and scientific should be the nutritional standards. We must know much more about the requirements of different types of stock at different levels of production and how these can best be supplied in the different feedingstuffs. We must also be able to tell the farmer much more about the effect of different rations on the quality of his product; for example, the relationship between the rations of dairy cows and low solids not fat in milk.

The urgent problems in animal health have changed markedly since the war. The outstanding work of the veterinary bacteriologist has brought us within sight of the eradication or control of

many of the most feared diseases caused by invading pathogenic organisms. We have still the menace of foot-and-mouth disease and of Johne's disease but even in these we are making steady progress. The farmers' worries have now moved to diseases of metabolic origin, where there is no invading organism to attack. In some instances these troubles can be definitely attributed to nutritional deficiencies, but the answer is rarely as simple as this. There is no direct way by which these conditions can be attacked. We can sometimes effect a cure by treatment if the animal is caught in time, but at the best production is lost; often the onset of the disease is so rapid that the animal is past help when it is found. The only real solution rests in a thorough knowledge of the physiological and biochemical processes in the normal animal, which will enable us to know how these are upset and distorted in the sick animal. Once we know the cause we are at least on the road to the prevention of a disease and it is prevention which the farmer wants.

The group of problems related to machinery and buildings has grown greatly in importance since the war. In meeting the shortage of manpower and its increased cost, British agriculture has become the most highly mechanised in the world. The production of standard machines is the task of the manufacturer; the research worker is concerned with the proper use in relation to the farming enterprise and, where no suitable machine is available for a process requiring mechanisation, in designing a prototype. He is also called upon to test existing machines in relation to the farmers' needs and to draw attention to their shortcomings.

Farm buildings are equally involved with labour requirements and call for the same type of studies in relation to the farming system they serve. Fortunately, or perhaps unfortunately, they do not wear out so quickly as machines and even where they are grossly inefficient it is often impossible to do more than to make a compromise reorganisation of the plan if the cost is to be justified by the saving in labour.

This is of necessity no more than the briefest survey of a huge and complicated task. The challenges to research from agriculture grow rather than diminish in number with the rise in efficiency of production. At the same time they become individually more difficult of solution, calling for great knowledge and skill on the part of the research worker as he delves more deeply into the fundamental process underlying the growth of crop and stock.

ECHOES from the Past

A policy for Science

'. . . Such of the above suggestions as we think deserving of the serious and earnest attention of Government, Parliament, and the Universities, and which we may term our desiderata, may be summed up in the following propositions:

'1st. That reforms shall take place gradually in the system of any of our Universities which do not at present exact a certain proficiency in physical science as a condition preliminary to obtaining a degree.

'2ndly. That the number of Professors of Physical Science at the Universities shall be increased, where necessary; but that at all events, by a redistribution of subjects, or other arrangements, provision should be made for effectually teaching all the various branches of physical science.

'3rdly. That Professors and Local Teachers shall be appointed to give lectures on Science in the chief provincial towns, for whose use philosophical apparatus shall be provided; and that arrangements shall be made for testing by examination the proficiency of those who attend such lectures.

'4thly. That the formation of Museums and Public Libraries in such towns, open to all classes, shall be encouraged and assisted in like manner as aid is now given to instruction in the principles of art; that all imposts shall by degrees be abolished that impede the diffusion of scientific knowledge; and such donations of national publications be made as above mentioned.

. . . . . .

'7thly. That an appropriate building, in some central situation in London, shall be provided at the cost of the nation, in which the principal Scientific Societies may be located together.

'8thly. That scientific offices shall be placed more nearly on a level, in respect to salary, with such other civil appointments as are an object of ambition to highly educated men; that the officers themselves shall be emancipated from all such interference as is calculated to obstruct the zealous performance of their duties; and that new scientific offices shall be created in some cases in which they are required.

'9thly. That facilities shall be given for transmitting and receiving scientific publications to and from our colonies and foreign parts.

'10thly and lastly. That a Board of Science shall be constituted, composed partly of persons holding offices under the Crown, and partly of men of the highest eminence in Science, which shall have the control and expenditure of the greater part at least of the public funds given for its advancement and encouragement, shall originate applications for pecuniary or other aid to science, and generally perform such functions as are above described, together with such others as Government or Parliament may think fit to impose upon it. . . .

'The 10th proposition, the establishment of the Board, is not advocated as a means of increasing privileges and emoluments, but as the best mode of accomplishing an important national object. . . .'

Extract from the Report of the Parliamentary Committee of the Association, Glasgow, 1855.

* * *

The Extraordinary Effects of Lightning

'. . . The circumstance to which this paper refers occurred on the passage of the New York packet from America to Liverpool in the year 1827. Soon after the commencement of the voyage, this vessel encountered a severe thunder-storm, and received a stroke of lightning which shattered the masts in several parts, and started some of the exterior planks

of the bends. This was in the morning before daylight. The weather continuing unsettled, and the air in a highly electric state, with water-spouts in various directions around—the captain, fearing another explosion from the highly charged atmosphere, put up a lightning conductor which he had on board. In the afternoon of the same day, the ship was a second time struck, but preserved by the conductor, though the iron of which it was composed was destroyed, and fell in melted globules upon the deck. No lives were lost, though some of the crew received heavy shocks: whilst one person, an invalid passenger, derived essential benefit from the electric discharge. Mr. Scoresby had an opportunity of examining the vessel immediately on her arrival in Liverpool, when, on investigating the condition of the iron on board, he found almost every article capable of permanent magnetism, with sensible polarity. Table knives and forks were capable of lifting needles or small nails, and one knife sustained a travelling-trunk key. Most of the watches on board suffered by the magnetic influence, especially those which were under the pillows of their owners in bed. These were all stopped, and on examination were found so highly magnetic, that portions of the steel-work were capable of suspension by each other, in a chain of three or four pieces. Of one of these pieces (the cap-spring) Mr. Scoresby made a pocket-compass, which was exhibited when his communication to the Association was made, and was observed to be, in all respects, a delicate and perfect instrument. . . .'

Extract from lecture by W. Scoresby, F.R.S., Oxford, 1832.

* * *

A School of Physical Science

'. . . The institution of the School of Physical Science (*in Oxford*) forms a most important feature in the recent changes, and will doubtless be productive of good results, provided that sufficient encouragement by way of reward be held out to those whose tastes lead them to devote themselves to those departments of knowledge, and that the compulsory arrangements in respect of other studies allow sufficient time to the student to accomplish his object. The great majority of physical students must necessarily belong to that class who have their subsistence to earn; and however earnest may be their zeal for mental improvement, there will be few candidates for the honours of the Physical School unless due encouragement be given to excellence in that department. . . .'

Chemistry of the Cell

'. . . In Chemistry I am informed that great activity has been displayed, especially in the organic department of the science. For several years past processes of substitution (or displacement of one element or organic group by another element or group more or less analogous) have been the main agents employed in investigation, and the results to which they have led have been truly wonderful; enabling the chemist to group together separate compounds of comparatively simple constitution into others much more complex, and thus to imitate, up to a certain point, the phenomena which take place within the growing plant or animal. It is not indeed to be anticipated that the chemist should ever be able to produce by the operations of the laboratory the arrangements of the elements in the forms of the vegetable cell or the animal fibre; but he may hope to succeed in preparing some of the complex results of secretion or of chemical changes produced within the living organism. . . .'

Extracts from the Presidential Address by The Rt. Hon. the Lord Wrottesley, Oxford, 1860.

SOME ASPECTS OF CRYSTAL PHYSICS

Part I. Electrons in Crystals

By Prof. G. F. J. GARLICK, D.Sc., F.INST.P.
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1. Atoms and the Solid State of Matter

The solid parts of the world around us have many varieties of appearance and texture and of other physical properties. They can be transparent, coloured, opaque, electrically conducting or insulating, etc. The solids of interest here are those of a crystalline nature—the metals, a very large number of non-metals and a class intermediate between these two which contains the semiconductors. The atoms of crystalline solids are arranged in orderly fashion in regularly repeating patterns which form the three-dimensional crystal lattice (e.g. see Fig. 1). This regularity makes the problem of explaining the properties of crystals in terms of

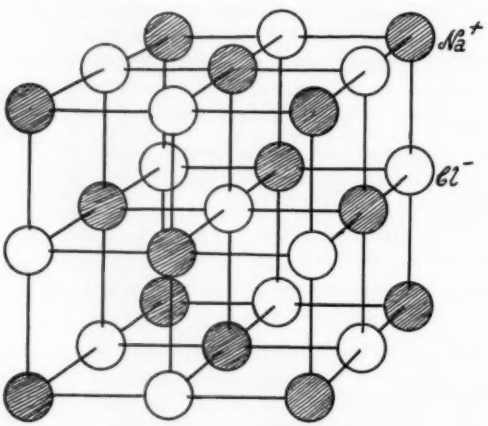


Fig. 1.—Crystal lattice of sodium chloride.

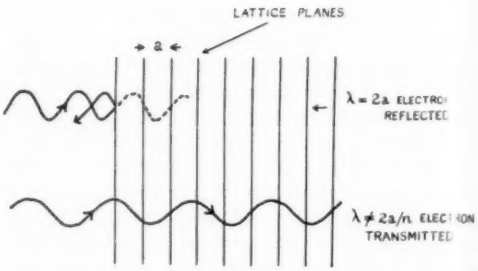


Fig. 2.—Diffraction of electrons by planes of lattice atoms.

the electrons their atoms possess very much easier than for an amorphous or disorganised solid. The individual atoms are very close together and their outermost or valence electrons are in fact shared amongst all the atoms of the crystal. To determine the macroscopic result of a given atomic constitution of a crystal the simple idea of electrons as minute charged particles is not sufficient. We have to make use of the fact that electrons have a wave-like nature.

2. Electrons as Waves

In 1924 Louis de Broglie, a French physicist, made the hypothesis that any particle of mass m and velocity v could be thought of as a kind of matter wave with a wavelength λ given by the simple relation:

$$\lambda = \frac{h}{mv} = \frac{h}{p} \qquad 1.$$

where p is the electron momentum and h is Planck's constant.

If we take the now well-established value of this constant then the valence electrons in crystals will

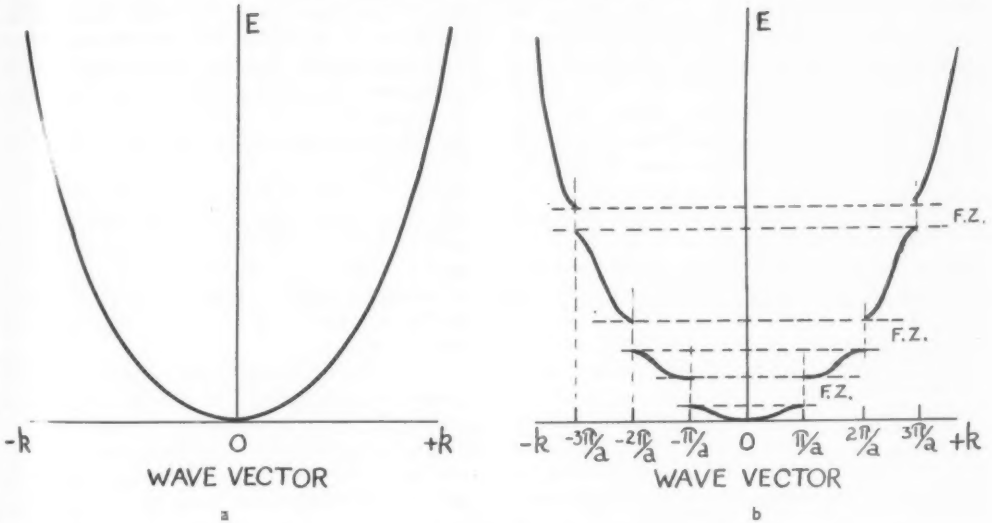


Fig. 3.—Relation between energy (E) and wave vector (k); (a) for free electron, (b) for electron in one-dimensional crystal lattice (F.Z. denotes forbidden energy zones).

have wavelengths of the order of 1 Ångstrom or 10^{-8} cm. (The electrons in the cathode ray beam of a TV tube have a wavelength of about 10^{-9} cm.)

Now it is well known that light waves can be selectively diffracted by the gratings used in modern spectrographs when their wavelengths have the right size relative to the regular spacing of the ruled lines of the grating. A crystal is a three-dimensional version of the optical grating and X-rays of wavelength ≈ 1 Å were first found to be diffracted by crystals in 1912. The diffraction of electrons by crystals, an experimental proof of their wave nature, was discovered in 1927 by Davisson and Germer in the U.S.A. and independently in this country by G. P. Thomson (now Sir George and President of the British Association). Let us consider the simple case in Fig. 2 of electron waves impinging normally on regularly spaced planes of crystal lattice atoms. They will pass into such a crystal unless their wavelength fits the condition for reflexion, first put forward for X-ray deflection by Sir W. Bragg, which is:

$$n\lambda = 2a \qquad 2.$$

where a is the lattice spacing and n is a whole number (the so-called order of the reflexion). With such wavelengths electrons cannot penetrate into the crystal or exist within it. If instead of wavelength we use the wave vector k, which is simply $2\pi/\lambda$, then this is closely related by equation 1 to the electron momentum and in free space to the electron energy E. For the latter case if we assume $E = mv^2/2$ the relation between E and k is:

$$E = h^2k^2/8\pi^2m \qquad 3.$$

and is shown graphically in Fig. 3*a*.

In a crystal the relation is more complex and is shown graphically in Fig. 3*b* for a simple one-dimensional crystal lattice of spacing a. We see clearly that there are gaps in the possible energies for electrons in crystals where forbidden values occur due to Bragg reflexion.

3. Energy Bands for electrons in Crystals

To make the above ideas a little more understood compare the possible energy states for electrons in a single, isolated atom with those in a crystal as shown schematically in Fig. 4*a* and *b* respectively. The very discrete states of the isolated atom broaden out in a crystal into bands separated by forbidden energy zones. These bands extend throughout the

crystal and electrons are no longer localised on individual atoms. The available electrons in a crystal pack into the lowest bands allowed in a two-by-two fashion for each individual level of a band. If the highest band with any electrons at all is not completely filled by them then a small external field will make the uppermost electrons move through the crystal and also move up into unoccupied levels just above in the same band. In this case the crystal is metallic and a good electrical conductor. If the highest occupied band is completely saturated with electrons, electric fields of ordinary strengths will have no effect since they cannot impart a net energy to the electrons (no immediately adjacent empty levels) and the crystal then behaves as an insulator.

Sometimes in such a saturation case as the last one above, the forbidden zone above the filled band is not too wide. Then random thermal 'jostling' of the atoms and electrons may 'push' some electrons into the next permitted zone where they can be influenced by an electric field and cause electrical conduction which increases rapidly with rise in temperature (due to increased thermal agitation). Such a crystal is a semiconductor. The spaces left behind in the filled band also contribute to the conduction behaving like electrons but with a positive charge and moving in the opposite direction—we call them *positive holes*. The band diagram for a semiconductor of the simplest or intrinsic kind is shown in Fig. 5. If the positive hole idea seems difficult it is useful to think of the analogy of a bubble in a spirit level which moves up the tilted tube.

The jump of electrons across the forbidden zone can be accomplished by absorption of light in which case we call the resulting conduction when an electric field is applied *photo-conduction*. Photo-conductors have very important applications such as the detection of infra-red light.

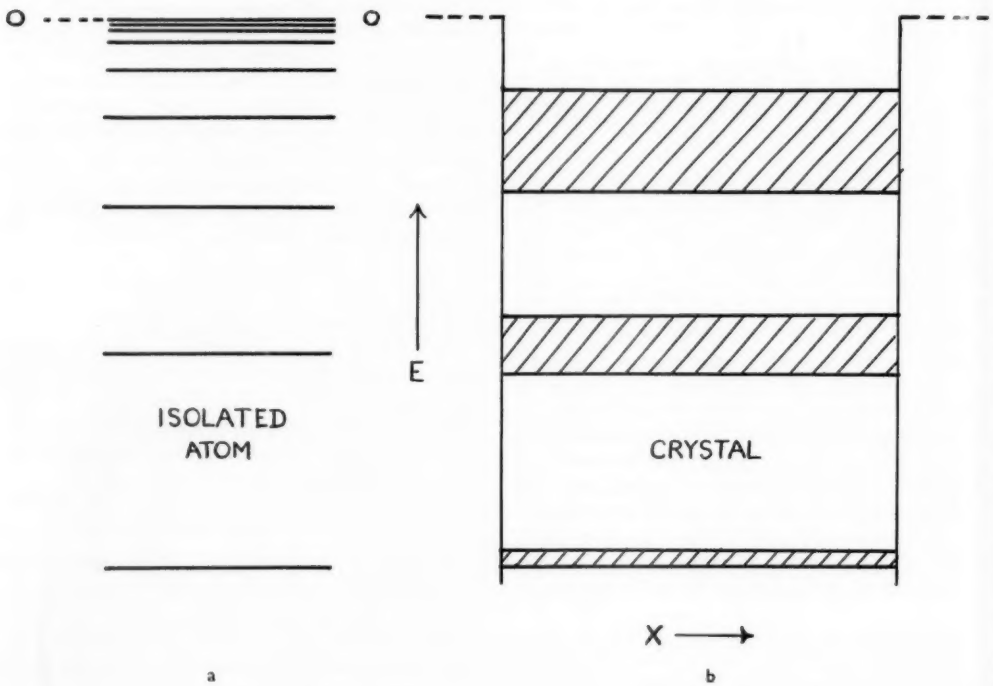


Fig. 4.—Energy level diagram for: (*a*) isolated atom, (*b*) electrons in crystals.

4. Practical Crystals, Impurities and imperfections

Practical crystals are never as perfect as the theoretical ones we have discussed above. They may have missing lattice atoms (lattice defects), flaws and contain impurity atoms, and in any case thermal agitation will upset an otherwise perfect crystal lattice. Defects and impurities provide localised states for electrons, some lying in forbidden energy zones of the perfect lattice. They strongly affect the crystal properties (e.g. a ruby has the same crystal lattice (aluminium oxide) as a white sapphire; its red colour is due to the presence of about 1 per cent chromium). Specific impurities can make a semiconductor like germanium or silicon conduct mainly by electron motion or mainly by hole motion. Proper combination of these two types of behaviour in one crystal can provide a transistor or crystal triode amplifier. However, the next section discusses a different group of crystalline solids with equally interesting properties.

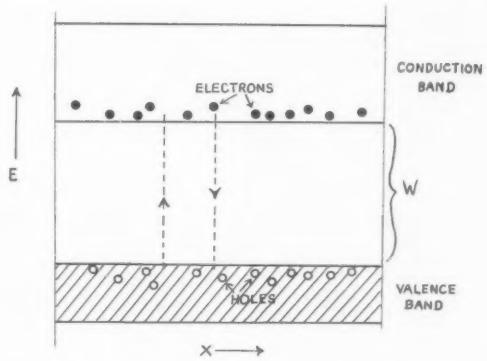


Fig. 5a.—Energy-band diagram for intrinsic semiconductor.

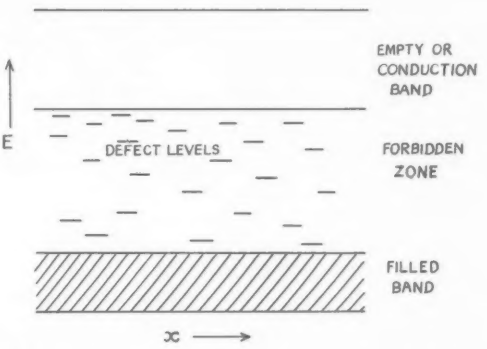


Fig. 5b.—Energy-band diagram for crystal with lattice defects and/or impurities.

Part II. Coloured Crystals as Model Solids

By R. V. Hesketh,* Ph.D., and E. E. Schneider, Dr.Phil.Nat., F.Inst.P.

King's College (University of Durham), Newcastle upon Tyne

There is one class of perfect insulators called alkali halides which can become conductors by suitable irradiation. These crystals demonstrate conduction processes in a particularly simple way and illustrate visibly some of the ideas of Part I. They are formed from an alkali metal, such as sodium or potassium, and a halogen, such as chlorine or bromine. Each metal atom readily gives up one electron, so that the solid is formed of positive alkali ions (e.g. Na^+) and negative halogen ions (e.g. Cl^-) and these are packed together in the closest possible manner. Since the halogen ions are much bigger than the sodium ions one may think of the structure as a close packing of halogen ions with sodium ions placed in a similar regular fashion between them. The crystal is held together by the attraction between positive and negative charges and its structure is illustrated by Fig. 1. The best known of these solids is common salt, sodium chloride, NaCl, which is crystalline although the crystals are very small. Their value as models lies in the fact that the alkali halides can easily be obtained in large single crystal blocks which are transparent so that one can see various imperfections deep in the crystal. It is because of the imperfections that we can find out about specific processes in solids.

The most interesting imperfections are those which give the crystals most striking and characteristic colours, yellow for NaCl, magenta for KCl, a beautiful blue for KBr. We have remarked that the halogen ions in the structure carry one electronic charge, so that if we remove one of them and replace

* Now on the staff of the Central Electricity Authority Research Laboratory.

FORMATION OF ELECTRON CENTRES

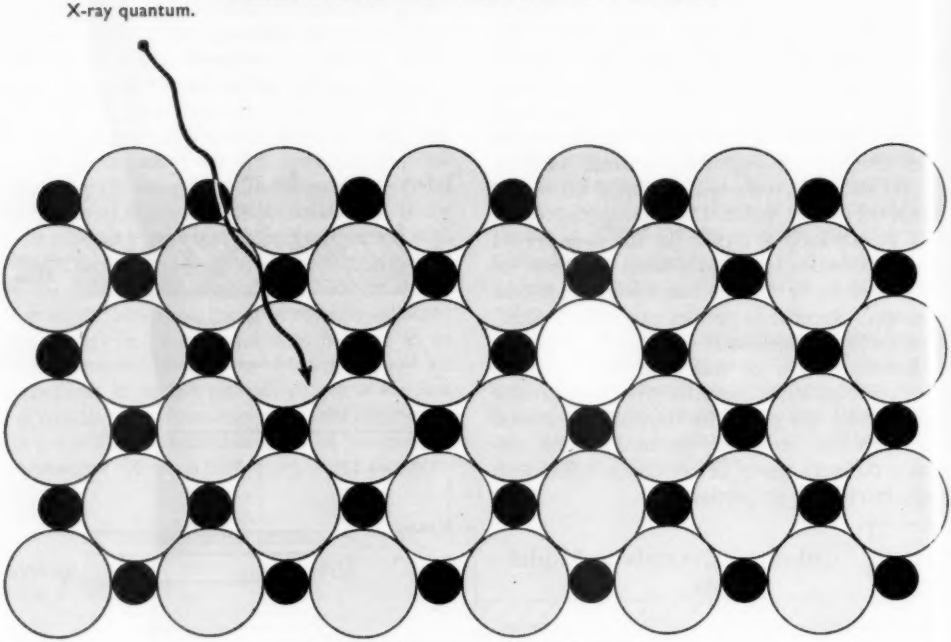


Fig. 6.—(*a*) Quantum absorbed in crystal.

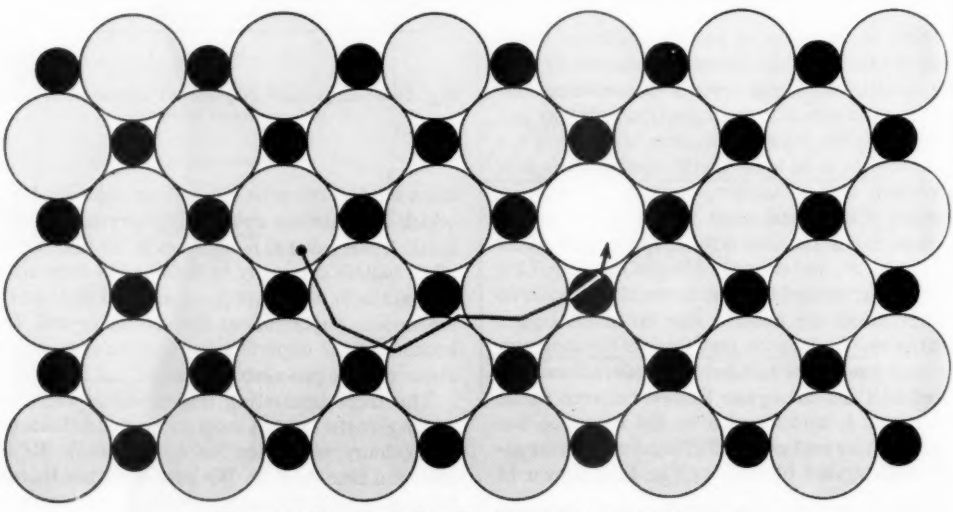
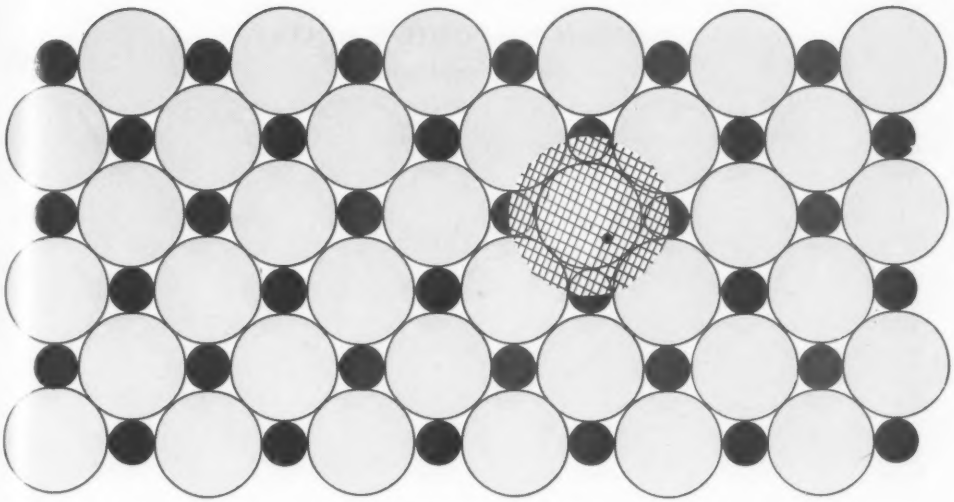


Fig. 6.—(*b*) Electron produced by X-rays moving through crystal.



(c) Electron trapped at vacancy.

Fig. 6.—Schematic illustration of electron centre formation.

it with something else which also has one electronic charge, the electrical balance of the crystal is not disturbed. Let us substitute an electron. This electron will stay where we put it because it is held by the surrounding positive charges on the alkali (e.g. Na^+) ions. However, the replacement of the halogen ion has disturbed the crystal for the following reason. The attractive forces holding the crystal together press the ions against each other, and removal of one ion removes a force from one side of its neighbours. These move to new positions as a result of the unbalanced forces. This happens even though we replace the halogen ion by an electron, because the electron is much smaller, and 'rattles like a pea' in the defect instead of being 'squeezed like a football'. We have thus introduced a disturbance into the regularity of the lattice and this again disturbs the energy levels, introducing two new energy levels for the electron which is at the site of the disturbance. These levels are in an otherwise forbidden range and one of them is close to the empty allowed energy range. Now the electron at the site of the imperfection is usually in the lower energy level, but it can go to the upper one if we supply it with the correct amount of energy. This energy is that of a photon of blue light for a trapped electron (or electron centre) in NaCl, and that of a photon of green light in KCl. We have created electron centres in these two crystals which make the NaCl yellow because they absorb the blue from the light falling on it and the KCl magenta because they absorb the green.

One way to create electron centres is to bombard the crystals with X-rays. Now let us take for granted for the moment that there are gaps in the crystal where halogen ions should be, known as vacant lattice sites, or vacancies (see Fig. 6). Electrons liberated by the X-rays arrive at these vacancies and stay there because of the attraction of the nearby sodium ions. Thus, the net result of X-irradiation is to transfer an electron from a halogen ion, leaving a halogen atom, and form an electron centre at a vacancy.

Let us now consider the halogen atom left by the removal of an electron. We refer to the absence of an electron from a halogen ion as the existence of a positive hole at the ion, a concept discussed in Part I. Fig. 7 shows how a positive hole may move through the crystal by the repeated transfer of an electron from one of its nearest neighbours. In a similar way to which an electron is captured at a vacancy from which a halogen ion is missing, a

MOTION OF POSITIVE HOLES

(Electron replacement).

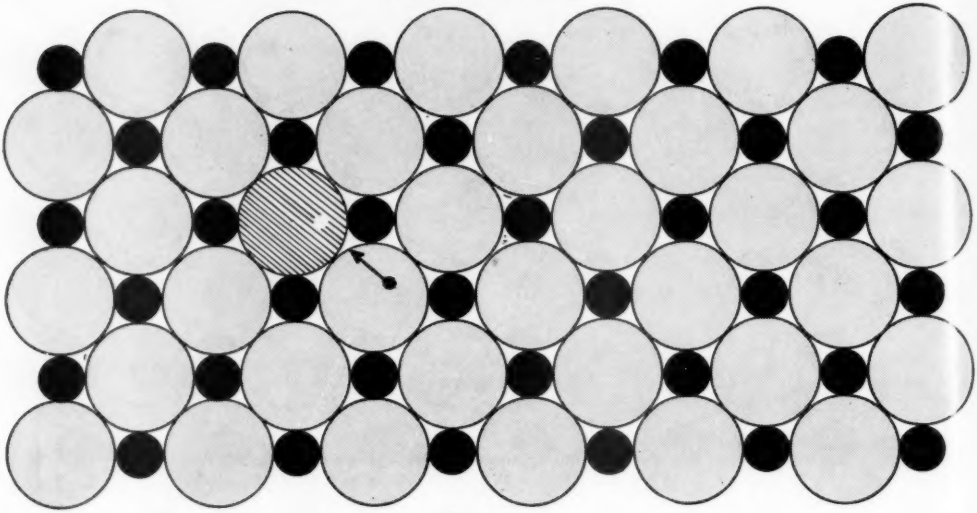


Fig. 7.—(*a*).

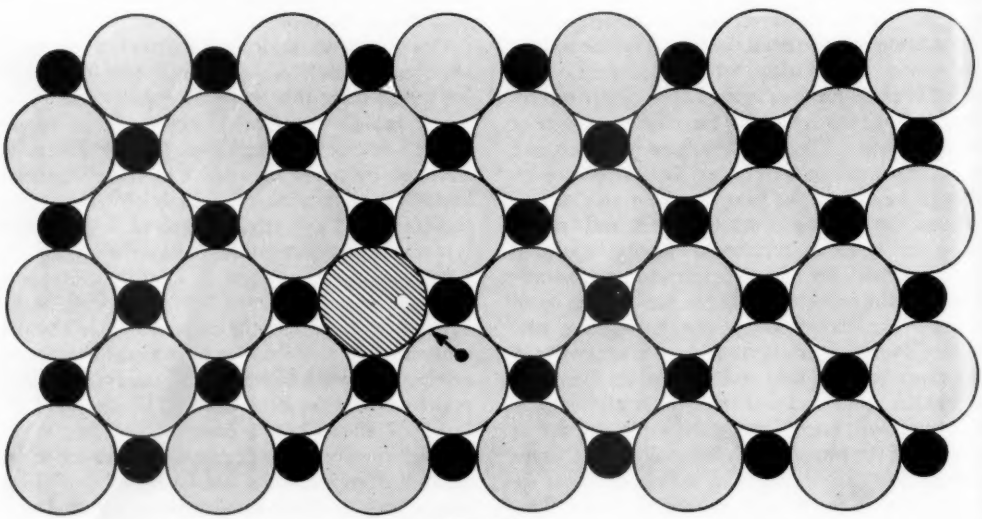
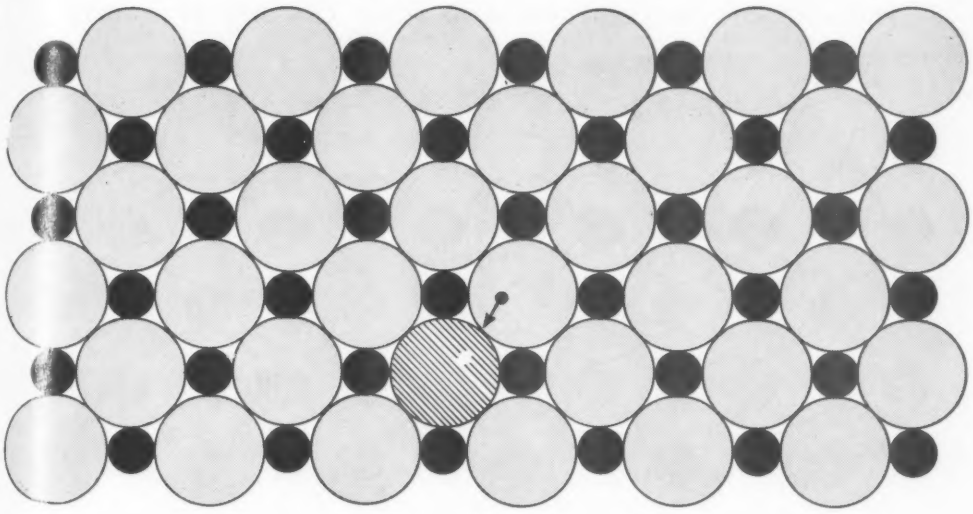


Fig. 7.—(*b*).



(c)

Fig. 7.—Schematic illustration of the motion of positive holes.

positive hole may be captured at a vacancy from which an alkali ion is missing (Fig. 8). This gives rise to a positive hole centre which is complementary to the electron centre, but leads to absorption of ultra-violet light beyond the visible region. The characteristic colour of such irradiated crystals is thus entirely due to electron centres.

Apart from the fact that the colouration process itself evolves the motion of electrons and holes, electronic motion can be induced in coloured crystals by the absorption of light. The absorption of a quantum of light of characteristic wavelength leaves the electron centre in the upper of the two energy levels, where the electron is more spread out in the crystal than in the case of the lower level shown in the figures. Thus heat energy of the crystal may completely liberate the electron from the vacancy. If this occurs, we may observe, on application of an electric field, the motion of the electrons in the field direction. This, of course, is an electric current and since we need to absorb light to make the first large energy step, we term it a photo-current (see Part I).

Similarly photo-currents may be produced which are carried by positive holes liberated from the complementary centres by the appropriate ultra-violet light. Coloured crystals are therefore photo-conductors in which electronic conduction processes can be studied in a simple manner.

A further most significant feature of the mechanism of colouration of crystals concerns the origin of the vacancies in which electron and hole centres are formed: most of them are created only by the irradiation with X-rays; they may also be created by irradiation with fast particles such as neutrons in a reactor (a rather similar effect explains the swelling of graphite in a reactor). This leads us into the field of radiation damage which deals with the disrupting effect of radiation on the arrangement of atoms in solids and the consequent changes in mechanical and other properties.

So far we have considered electron and hole centres formed in equal numbers by high-energy bombardment. When we disturb such a crystal by illumination or by heating, the complementary electrons and holes destroy each other, so that our experiments can only be of short duration. To perform more extended experiments we need to be able to follow the motion of one type of imperfection without its destruction by the other. Fortunately, crystals may be coloured by only one type of centre. To create only electron centres the crystal

PRODUCTION OF ELECTRON AND HOLE CENTRES BY X-RAYS

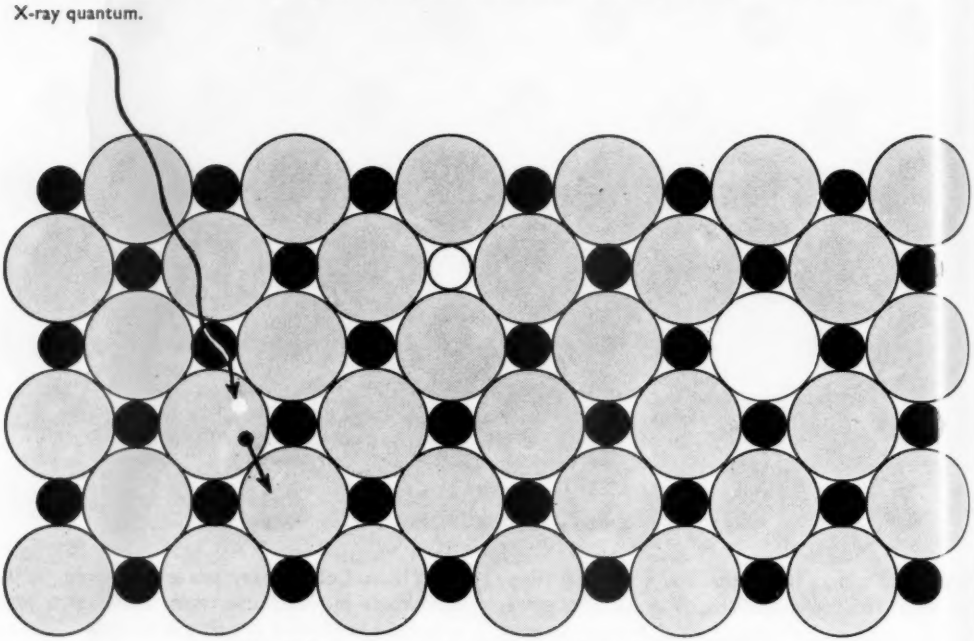


Fig. 8.—(*a*) Electron hole pair produced by absorption of quantum.

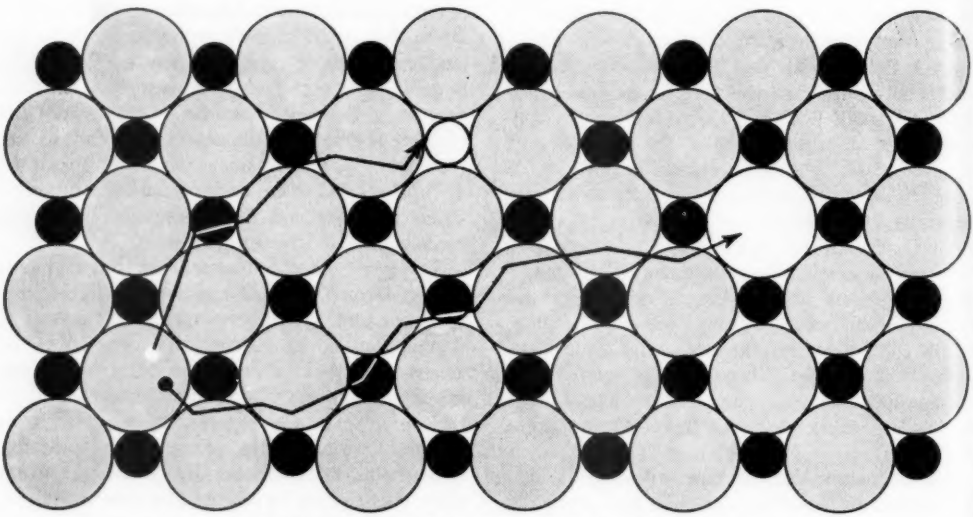
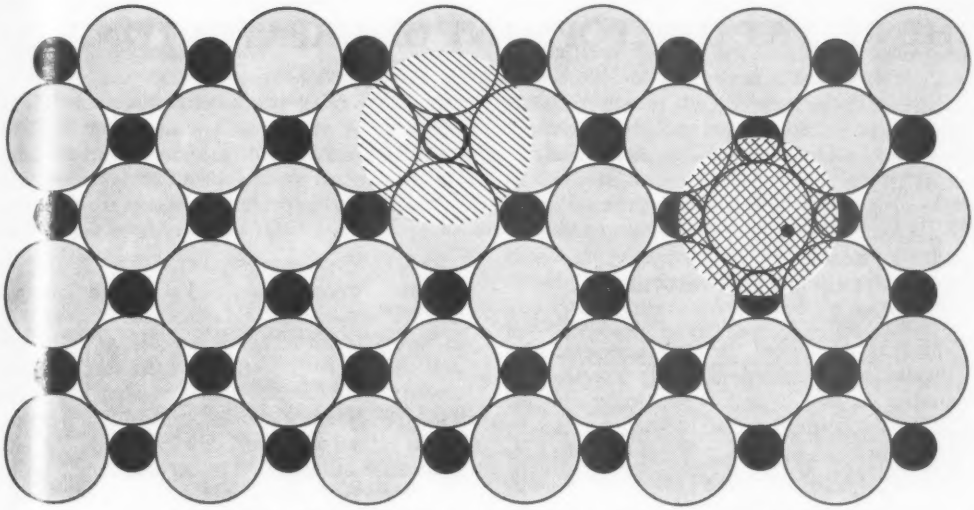


Fig. 8.—(*b*) Motion of electron and hole through crystal.



(c) Electron and hole centres formed at negative and positive ion vacancies.

Fig. 8.—Schematic illustration of the production of electron and hole centres by X-rays.

is heated in a vapour of the alkali metal and then cooled rapidly. To create only hole centres the crystal is heated in the vapour of the halogen. Alternatively electrons may be directly injected at high temperature. A crystal containing only electron centres may give electrical conductivity by electron motion, that is to say, it is an *n*-type semiconductor, like silicon or germanium doped with Group V elements, such as arsenic. Similarly a crystal which has been heated in halogen vapour and contains only positive hole centres is a *p*-type semiconductor.

By heat treatment of a crystal containing only electron centres it is possible to make centres coagulate along lines of imperfection in the crystal, the so-called dislocation lines, so that these become visible and may be photographed. This technique is of extreme importance since dislocations, which can be regarded as elementary deformations of crystalline lattices, play a major role in our understanding of such mechanical properties of solids as plastic deformation, creep, etc.: it allows model experiments in which the intricate pattern and interaction of dislocation lines deep inside the crystal can be visibly demonstrated.

Conclusion

It is clear that by treating electrons as waves many different properties of crystalline solids may be explained. Quantisation of energy occurs, though in a more complex manner than for isolated atoms. The energy band model for electrons in crystals when modified to allow for defects and impurities can explain effects such as semi- and photo-conduction. Its main implications can be quite exhaustively tested in the case of coloured alkali halide crystals which are almost ideal experimentally, linking together various interests in solid state physics.

THE RECENT DEVELOPMENT OF GREATER LONDON*

By A. G. POWELL *Senior Research Officer (London Region) Ministry of Housing and Local Government*

THE BARLOW REPORT

Twenty years ago, in August 1939, the Barlow Commission completed the first nation-wide investigation into the problems arising from the concentration of new industrial population into the growing conurbations. The conurbation can be regarded as man's ultimate masterpiece in the control of his physical environment—producing the almost wholly man-made landscape. This paper examines, with reference to Greater London, how far man has been able to control his own work.

The Barlow Report examines the pre-war functions of the London conurbation and the advantages flowing from them. It is the capital city and centre of national administration, an international focus of finance and commerce and the greatest distribution centre in the country. These produce a large and relatively highly paid population working in administrative and service trades and they in turn produce a great consumer market. Market and population act and re-act upon each other to build up an ever-increasing concentration of people and industries which in turn generates facilities for education, medicine, culture and recreation which are unrivalled elsewhere in Britain.

These advantages were off-set by overriding disadvantages. Strategic problems arose from the prospect of mass bombing—and the revolution in this context since 1939 needs no further comment. Social problems arose from slums and overcrowding, lack of open space and sunshine and prevalence of smoke, dirt, fog and noise. Economic problems arose from traffic congestion, high land values, high rents, financial handicaps and long journeys to work.

* The author wishes to acknowledge the assistance given by the Ministry of Housing and Local Government; in particular by the Research staff of London Region and the Maps Office. Any views expressed in the paper are purely personal.

Barlow summarises London as 'an immense liability' and, in a strongly worded Minority Report, as 'an evil which should be remedied at the earliest possible moment', bearing in mind that 'the continued drift of the industrial population to London and the Home Counties constitutes a social, economic and strategical problem which demands immediate attention'. The Report concludes by recommending national and regional planning and research into the problems and their underlying causes. It was the first of many which produced the social revolution and the Welfare State.

THE GREATER LONDON PLAN

The machinery for the control of Greater London followed rapidly. Between 1942 and 1944, Patrick Abercrombie, the mainspring of the Barlow Minority Reports, produced the Greater London Plan whose basic principles were accepted by the Government in 1946. The Distribution of Industry and Town Planning Acts necessary to implement the control of industrial and population growth had become law by 1952.

The main objectives of the Greater London Plan are:

(1) To restrain urban sprawl by means of a green belt.

(2) To provide better living conditions in the congested area of inner London after reducing its population to $1\frac{1}{4}$ million below the 1938 level.

(3) To reduce journeys to work by a redistribution of population and employment to new and expanded towns beyond the green belt.

(4) To reduce traffic congestion and improve communication.

The Plan assumed that the population of the area would not rise above its 1938 level of 10,150,000,

that industrial growth generally would be restrained and that new industry would only be permitted in very special circumstances.

The Development Plans produced by the ten local planning authorities covering Greater London retained the broad outline of the Abercrombie proposals. All these plans have received Government approval after modifications designed mainly to reduce the amount of industrial land available.

CHANGING METROPOLITAN FUNCTIONS

The generation since Barlow has seen considerable changes in emphasis in the pre-war functions of London and the evolution of new ones which the Commission could, at best, only see dimly.

The war left London more than ever before the undisputed centre of Western Europe. It is difficult to quantify the effect of this change on the growth of London but it has certainly been a factor in the expansion of activity and office space at the centre. Neither Barlow nor Abercrombie could have foreseen that technical advances in air transport would now require over 25,000 workers at London Airport.

The re-orientation of the national economy since the war, based on an imperative need to export at competitive prices, could do no other than re-emphasise the significance of London as the premier port of Britain. The total tonnage of shipping using the Port of London in 1958 was 20 per cent greater than in 1938 (75 million tons, cf. 62 million). The need to export is our road to survival; the focal point of national economic policy to which all other considerations take second place and to which no serious challenge can be entertained. Its effect has been to limit the extent to which restrictions on industrial growth can be rigidly enforced in London or elsewhere. The emergence of new markets produced a demand for goods which called heavily on the factories of Greater London and the West Midlands. The national communications network is such that exports of capital and consumer goods, especially to Europe, Africa and the Southern Hemisphere are inevitably channelled through the London docks. The new motorways only sharpen the national focus on London.

Social and economic changes in the country have had their effects on land use in the metropolis. The Welfare State has brought increased numbers of administrative workers into the offices of Government Departments and Boards. Still more significant is the aggregate increase of office workers in commerce, notably in new industrial groupings and 'consortia' and in insurance and finance. All of these are part of the economic machine which is essential to improve our standard of living.

The new office blocks in central London are part of this machinery. The 46 million sq. ft. of new offices for which approval has been given since 1948 is greater than many would like to see, but it is the long overdue modernisation of the heart of Britain, delayed by depression in the 'thirties, then by war and finally by the post-war priority given to housing and industrial production. Redevelopment and modernisation of this nerve centre of the nation are vital if Britain is to keep pace with her competitors. This is not to say that every office and every office worker in central London is vital to the economic life of the country. Much could operate successfully in other parts of the London Region. How much, in the absence of collated data, it is impossible to say. What is reasonably clear is that office employment in the Metropolitan Area as a whole will continue to increase as long as the economic activity of the country does likewise.

Barlow emphasised the need to control new factory building and prevent the drift of new industry to London. But are new factories the real problem? New industry is rarely a case of spontaneous generation. Normally it is an organic evolution of one process or one product from another. The television and electronics industries, now so heavily concentrated into Greater London, are the natural growth of the pre-war electrical and radio industries, commonly occupying the same premises extended by say 10,000 sq. ft. for storage, by 6000 sq. ft. for a canteen, by 8000 sq. ft. for a new production line and 3000 sq. ft. for a research and development unit. It is the last of these which germinates the seeds of industrial growth.

Extension and modernisation of existing factories is the main problem in controlling the industrial population of Greater London. There is no direct control of employment and much of the additional employment which does occur is spread throughout existing factories without any new building at all. Much more arises from the development of service industries which are essential to the increase of living standards within the Region. More still arises from the expansion of office employment. Available

statistics suggest that additional employment in the London conurbation arising from schemes requiring a Board of Trade certificate account for less than 20 per cent of the total annual increase in the London labour force—and most of this could not reasonably be moved elsewhere.

In fact, the operation of industrial controls by the Board of Trade in the London area is almost as tight as public opinion in a democratic society is prepared to accept. A marginal percentage of the additional floor space approved by the Board and the planning authorities could conceivably have been forced out of London by a slightly more stringent policy, but it could never be a significant amount. The industrial population of London could conceivably be further limited, at a price, by new controls on vacant premises and by closer control over factories of up to 10,000 sq. ft. Experience shows that high costs, averaging about £100,000 an acre, make the purchase of vacant factories quite impossible except as part of imminent redevelopment schemes.

The conclusion must be that the further expansion of industrial and allied employment in and around London is inevitable. The national interest and economic forces at work are too strong to be reversed. The brakes can be applied as hard as possible, new controls can be devised, further detailed research into the organisation, cost and operation of industry and commerce can be undertaken but the continued economic expansion of South-East England as a whole is a basic economic fact which must underlie all realistic planning for the future. Plans cannot be negative in this respect;

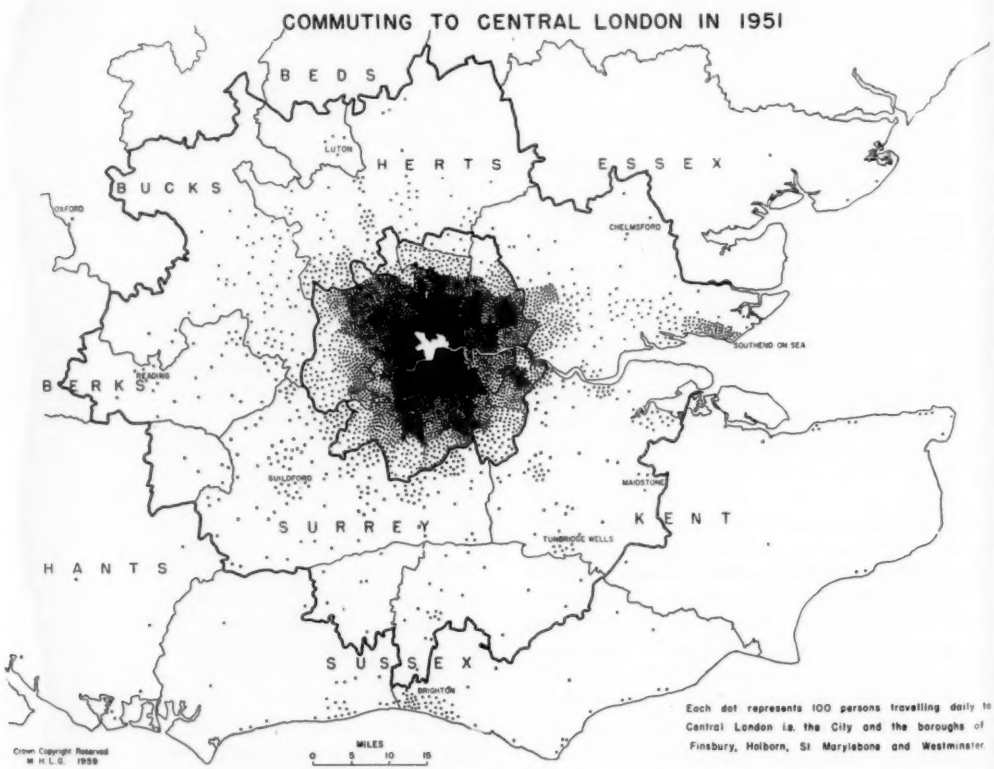


Fig. 1.

they must provide for expansion—controlled as tightly as possible, but expansion nevertheless—of general economic activity within easy reach of London's geographical advantages.

THE LONDON REGION

What has been the effect of the various new forces at work in the past generation? The daily movement of workers to central London gives a first indication of what the London Region is. Fig. 1 shows clearly that the daily influence of London in 1951 extended in some force as far afield as Brighton and Southend and in lesser degree to Luton and Reading. This Region has been consolidated by the changing distribution of population and employment between 1951 and 1958.

(1) Population Changes

General Register Office statistics show that, with the exception of its periphery, every district in the main built-up area of London had a smaller population in 1958 than in 1951. From Harrow in the north to Croydon in the south, from Dagenham in the east to Heston in the west the absolute decrease in population is continuous.

The overall decrease is of the order of 245,000. Allowing for natural increase, total migration from it has been about 410,000 or 60,000 a year.

Examination of the electoral population of civil parishes shows a great wave of continuous population increase surrounding the London conurbation. The average rate of increase in England and Wales between 1951 and 1958 was 3·3 per cent but most of the towns and villages shown in Fig. 2 increased by 10 per cent or more.

This belt of increase is the most significant feature in the pattern of population change in the vicinity of London during the 'fifties. Converted to a total population, the belt contains 660,000 or 18 per cent more people than in 1951. It completely encircles London; it covers most if not all of the Metropolitan Green Belt; it embraces and passes beyond all the eight London new towns and its tentacles extend along every major route from London—especially in the area from the north to the west and south-west.

It would be wrong to think of this only as a movement from London. Every town within it has expanded as an industrial centre or a dormitory—usually as both. The new towns, in which big population increases are to be expected are, like every other town in the area, surrounded by villages whose original character is being lost by the spread, however well planned it may be, of private housing. Here, in fact, is a perfect example of the conurbation process.

This is the contemporary Greater London. Hemel Hempstead, Romford, Watford and Slough—even Luton, Reading, Gillingham and Southend are closely inter-linked by a daily interchange of workers and are increasingly tied to central London by the ebb and flow of a great tide of commuters. This flow is probably 33 per cent greater now than in 1951 when 240,000 workers moved into the conurbation daily.

By taking every county district which contains any substantial part of the main belt of increase, the contemporary London Region (Fig. 3) can be defined as a roughly circular area with a radius of 40–50 miles from central London and a 1958 population of almost exactly twelve million. I emphasise 'the contemporary region', for here is an organic whole which is still growing.*

The net increase of population in the Region is 400,000 but the overall pattern of change can be accounted for almost entirely by a redistribution of the 1952 population as expanded by natural change. There are indications of a substantial gross turnover, but, after allowing for natural increase and demobilisation from the Forces, net migration into the Region between 1952 and 1958 is only about 45,000 or 11 per cent of the total change. Between 1932 and 1938 immigration to the smaller Abercrombie region was 441,000.

The redistribution of population or the 'overspill' across the conurbation boundary has taken place as a result of both planned and voluntary movements. Over 175,000 people were moved in planned schemes between 1952 and 1958:

(*a*) 120,000 to the eight London new towns;
(*b*) 45,000 to L.C.C. estates beyond the conurbation;
(*c*) 10,000 to the more recently developed expanded towns.

These planned movements demonstrate that neither people nor industries are prepared to move

* Since the Region was originally defined (as in Fig. 3) in 1956 there appears to be a case for adding Basingstoke U.D. and Basingstoke R.D.

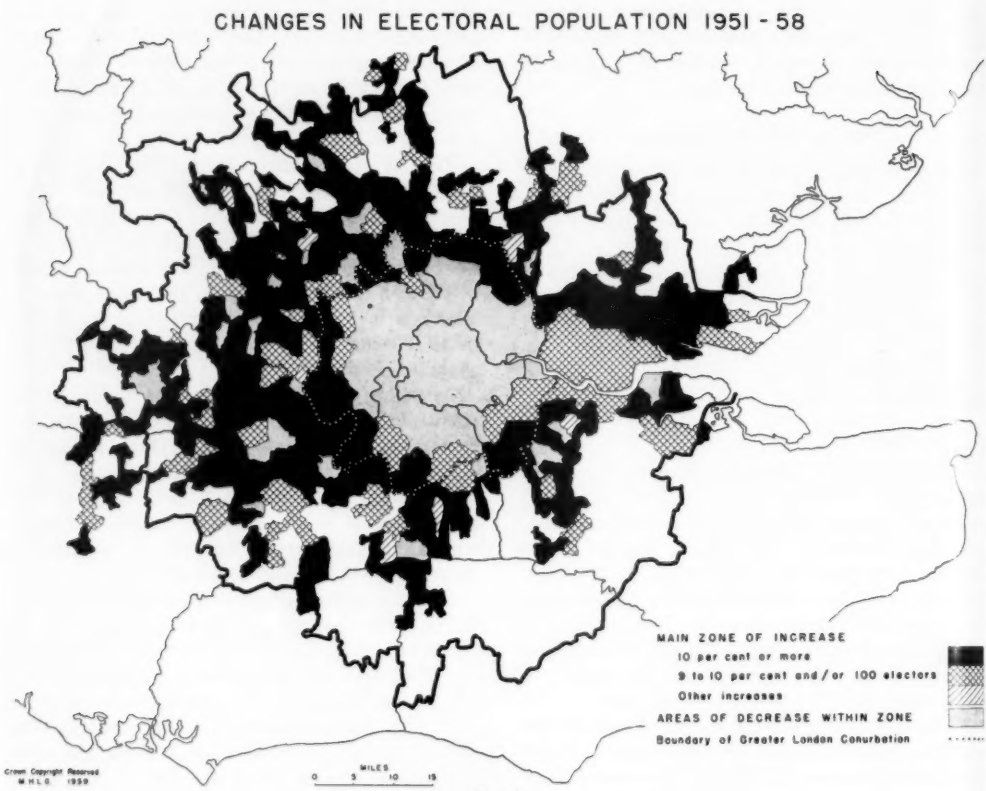

CHANGES IN ELECTORAL POPULATION 1951 - 58
MAIN ZONE OF INCREASE
10 per cent or more
9 to 10 per cent and/or 100 electors
Other increases
AREAS OF DECREASE WITHIN ZONE
Boundary of Greater London Conurbation
MILES
0 5 10 15
Crown Copyright Reserved
M.H.L.G. 1959

Fig. 2.

far. In fact firms and families have moved to the smallest possible extent and rarely beyond reasonable daily contact with their previous business and social connections. Fifty-eight per cent of Londoners moving to Hemel Hempstead have come from Middlesex, 66 per cent of those in Harlow from Middlesex and Metropolitan Essex and 84 per cent of those in Crawley from Surrey, Kent and the County of London.

A further 180,000 people have moved privately from the conurbation to fill in the residential areas in the towns and villages in and beyond the Green Belt—and they have filled them so completely that very little of the residential land originally earmarked to last until 1971 still remains undeveloped. Here is one of the problems of the immediate future, for the outward tide shows no sign of halting. Yet the Green Belt is specifically intended to contain the sprawl of London and to be inviolate and is being extended to at least twice its existing depth in most of the Home Counties.

The social forces which underlie this 'voluntary overspill' from London are much the same as those which produced the suburban development of the past; indeed this Outer London area is the suburbia of the motor car age. Electrification and diesel development on the railways have opened up new 'living room' for commuters—notably along the Chelmsford–Southend and East Kent routes, soon to be followed by improvements on those to Aylesbury, Luton, Hitchin, Clacton and Bishop's Stortford. Still more, the great increase in car ownership has extended the area within easy reach of central London. The 1,050,000 private cars registered in

the London Transport area in 1958 was almost 100 per cent greater than the 550,000 registered in 1952. Cars are being used in ever-increasing numbers to reach the nearest main line railways which, since 1952, have brought an additional 10,000 commuters a year into central London termini during the morning rush hour.

The population movements have taken place while the national level of employment was higher than ever before and when there was no vital necessity to move far in search of work. Yet, although net immigration is small, Ministry of Labour records show a strong flow of workers towards London and the south-east. The population and employment statistics together suggest that there is a great and continuous turnover of population*; with retired people leaving the Region and being replaced by somewhat larger numbers of younger working persons.

It would appear that young workers are being drawn, into central London especially, from all parts of the country. When they marry they make an initial home broadly within the County of London. As the family grows the tendency is to move out into the suburbs and, later, possibly out into the country beyond the suburbs—followed by ultimate retirement away from London entirely. There can be little doubt that a cycle of migration of this type is in operation. If the 1961 census proves its existence, then the migration cycle provides the basic mechanism for the expansion of London. This mechanism cannot be checked whilst the economic life of London remains as vigorous as it is today. Overspill from London must be faced as a continuing process—as indeed it has been from the sixteenth century onwards.

(2) Employment Changes

If population movements of the nature and volume described were accompanied by a comparable re-distribution of employment, then the pressure on the conurbation would be reduced as Barlow and the Development Plans proposed.

In a recent paper on location of industry read to the Town Planning Institute,† Professor Sykes analysed changes in the insured population of Standard Regions between 1949 and 1957. He drew attention to the high percentage increases in the Eastern and Southern Regions (18 per cent and 17·5 per cent respectively) and traced the effect of strict locational control in the relatively low increase of 7·7 per cent in the London and South-Eastern Region. He did not mention that this London percentage represents an increase in absolute numbers which is more than twice as great as that in any other Region. The Standard Regions, originally devised for Civil Defence purposes in the 'thirties, might well have been specially designed to camouflage the true picture of the London Region. If the Ministry of Labour's detailed statistics are reshuffled into a more significant geographical pattern, the picture is far less re-assuring. Sykes's tables show that nearly 51 per cent of the increase in insured workers in England and Wales occurred in the three South-Eastern Regions, but he did not possess the detailed evidence to show that most of that increase was concentrated within forty miles of central London in the geographical London Region. Between 1952‡ and 1958 the total working population of England and Wales increased by 978,000 or 5 per cent. In the London Region as defined here the increase was 400,000 or over 7 per cent. The Region, with 27 per cent of the population of England and Wales received over 40 per cent of the additional employment. Moreover, the built-up area of the London conurbation itself received 21 per cent of the national increase and no less than 12 per cent of the national total appears to be concentrated at the centre—in the nine square miles which contains the metropolitan administrative, business and shopping centres. This scarcely seems to conform with Barlow's hopes for control of the southward drift of employment.

This substantial increase in the insured population is difficult to reconcile with the apparent fact of little net immigration into the Region. It must mean that the ratio of insured workers to total population is rising. Within the Region the 1958 ratio of 471 insured workers per 1000 population is 18 per thousand above the 1952 figure.

Allowing for this factor, we cannot expect the conurbation to show a decrease in employment even

* See Bowen: 'Urbanisation and Population growth in England and Wales. *Yorks. Bulletin of Economic and Social Research* (Nov. 1958).

† *Journal of the Town Planning Institute* (May 1959).

‡ Employment statistics for 1951 are not directly comparable with those for 1958; those for 1952 are comparable.

though its population dropped by about 135,000 for, assuming the ratio to operate equally over the Region, the remaining 8¼ million would have produced an additional 85,000 workers. In short, if the 400,000 additional workers in the Region were distributed in proportion to the redistributed population, the increases would be 85,000 in the conurbation and 315,000 beyond it.

The actual pattern of employment change varies widely from this and the conurbation in fact gained 205,000 or 120,000 more than the theoretical figure while the outer areas gained 195,000 or 120,000 less than would be required to match the population change.

Fig. 4 shows the detailed geographical distribution of employment changes against a slightly generalised background of population change. It is a picture of maldistribution of population and employment. The biggest increases have taken place in those areas in which the population is falling.

Fig. 3.

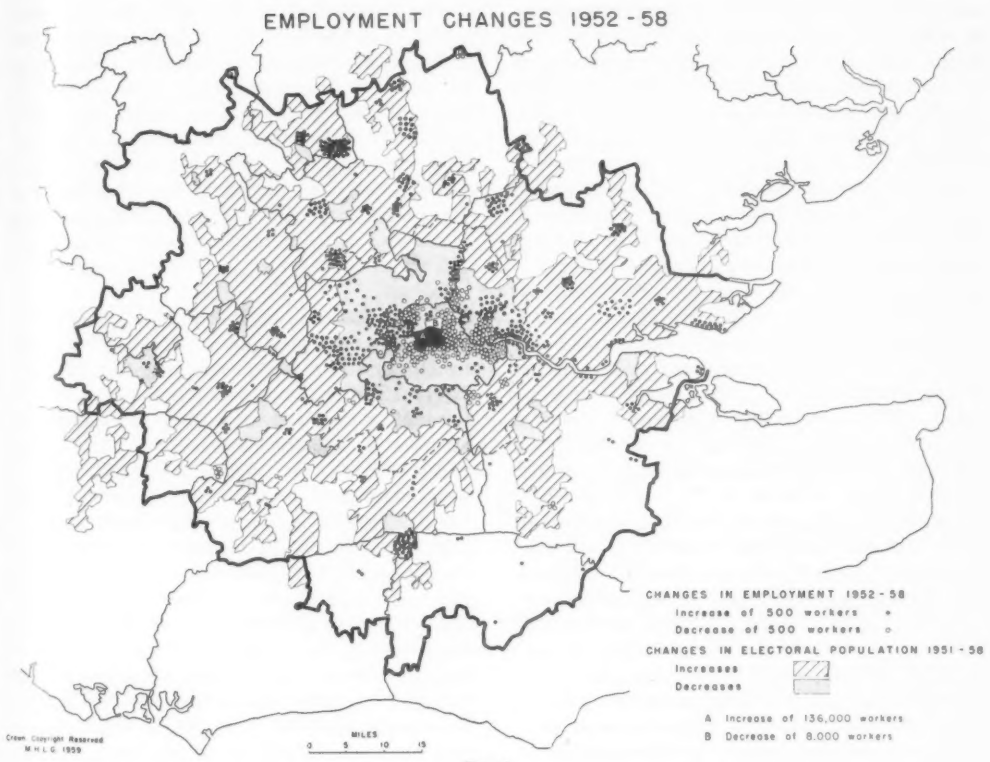


Fig. 4.

Changes in employment and movements of population are not in harmony.

The main points of geographical interest in the distribution of additional workers are:

Firstly, the attraction of central London itself. The statistics of employment in the central area are suspect, but at face value they show that the increase in employment at the centre since 1952 has been about 20,000 a year. True manufacture in this area is very small and the statistics merely underline the rapid increase in office employment.

Secondly, the steady evolution of industry and factory expansion in Park Royal, Wembley, the Lea and Wandle Valleys and along the North Circular and Great West Roads is reflected in the increased employment in all the traditional manufacturing areas—with the very notable exception of those parts of the County of London outside the centre which show the only significant concentration of decreasing employment.

Thirdly, the growth of new centres around the whole periphery of the conurbation. Sheerwater, Chertsey, Colnbrook, Ruislip, Borehamwood, Cheshunt, Debden, Hainault, Harold Hill and St. Mary Cray are some of the many new industrial estates on the edges of the Green Belt. The greatest concentration of all lies in western Middlesex, especially around London Airport (which itself employs over 26,000 workers—equivalent to the total employed in St. Albans or Harrogate or more than twice the current employment in Stevenage). This peripheral development is the continuation of a long-standing trend and is an integral part of the mechanics of conurban growth. Industry moves and expands—population follows. The effect of the green belt, which has been well held against

considerable pressure in West Middlesex (applications have been refused for 10,000 acres of residential development), is seen in the correlation between expansion of employment around London Airport and population growth in the Thames Valley and Chiltern areas of Berkshire and Buckinghamshire.

Fourthly, the unique physical and economic advantages of Thames-side itself have brought their share of industrial expansion. The London River brings bulk imports of oil, timber, wood pulp, phosphates and gas to South Essex and North Kent. It facilitates re-export of some of these goods and the export of such local materials as cement and Ford cars. Many new and enlarged power stations also play their part in the expanding riverside but, except for Fords, the Thames-side industries are extensive land users at a low density of workers per acre. All, including Ford, are highly automatic in operation.

Lastly, two points must be made on developments beyond the Green Belt. The industrial growth of the new towns is outstanding. By mid-1958 they had provided new manufacturing employment for over 40,000 workers as compared with a new population of 173,000 (130,000 from London). At present industrial provision in the new towns is in advance of population movements.

On the other hand, the widespread expansion of industry in almost every town and village of Greater London north of the Thames has promoted further conurban growth. Employment around Watford has increased by over 9000 (16 per cent) in six years, around St. Albans the increase is 3800 (15 per cent), around Romford and Hornchurch it is 7500 (20 per cent).

Former villages, particularly those along main radial roads, have their own share of expansion in similar or even greater proportion. London Colney and Welham Green are both bursting at the seams between Barnet and St. Albans. The paper, printing, engineering, metal and food industries of King's Langley are creating a pressure for housing which bids well to close the gap between Watford and Hemel Hempstead.

It is this general spread of small-scale industrialisation which, to use a geological metaphor, provides the matrix which welds together the larger, independent urban blocks into the solid conglomerate of the conurbation.

On the periphery of the Region the expansion continues in Reading, Chelmsford, Southend and above all, in Luton and Dunstable. These towns are increasingly drawing their labour from the fringes of the London pool; their dormitory villages are shared with London commuters. Comparatively little additional employment has arisen to the south-east of London where the importance of communications with the rest of Britain soon becomes obvious, leaving southern Surrey and most of Kent as rural backwaters on the 'wrong' side of London.

The modern consumer and capital goods which go to make our rising material standards of living are all too well represented among the industries involved in the expansion of London. They include remote control apparatus, special alloys and plastics, precision engineering, scientific equipment, T.V., radar and electronics, cosmetics and pharmaceutical chemicals, cars and aircraft, ballistics and computers, photographic equipment, business machinery and research and technological development of all types from nuclear power and fuel utilisation to the form and content of meat pies. These industries are housed in modern factories with modern plant, with a great market on their immediate doorstep and the greatest cargo port in Britain readily at hand to provide facilities for export to all parts of the world. If general depression were ever to hit the country again can there be any doubt that the new industries of Greater London, which maintain the lowest unemployment rate of any part of Britain, would again weather the storm as they did in the 'thirties better than any other part of the country? And can there be any doubt that, in the future as in the past, the unequal distribution of unemployment would bring a flood of immigrant labour into the economically favoured south-east?

We are therefore faced with an industrial extension of the London conurbation stretching in an almost continuous Thames-side belt from Reading to Southend, which provides a base for an even greater fan of development extending to the north, north-west and north-east along every artery leading outwards from the heart of this new industrial Britain. The extended conurbation consists basically of a number of industrial centres, expanding independently and with industrial workers travelling not much more than ten miles from their

home to work. These separate industrial entities are knit together into a composite and recognisably greater whole firstly, by the inter-movement of workers between them and secondly, by the superimposition upon them of the great and increasing daily flow of commuters to central London which forms a web uniting all parts of the whole and which is further re-inforced by the daily flows to the shopping and entertainment areas at the centre.

SOME FUTURE PROBLEMS

The overall picture of the London Region as shown in Fig. 5 is one of a compact urban core in the existing conurbation surrounded by the skeleton of a vast concentric extension of it which is 80–100 miles across. How far is this skeleton likely to fill out in the flesh? Given full employment, the growth of the working population must continue. If unemployment rises, the pressure on London may well increase. But, even without these considerations, the seeds of continued urban expansion are already present. At least three factors are likely to make substantial new demands on land.

Firstly, current town planning is based on development and redevelopment to standards appropriate to modern conditions. These are seen in new schools, factories and housing estates, and, comprehensively, in the new towns. Redevelopment to the new standards is only just beginning but, at least in the early years, it must inevitably create a growing pressure for more land.

Secondly, the 'post-war bulge', which has already made its impact on land for schools, will shortly appear as a pool of labour requiring employment and, later, housing. In the new towns, from 1963 onwards, school-leavers will be adding between 7 per cent and 10 per cent to the present labour force each year. Smaller percentage increases will occur elsewhere. More factory and office space will be required. Industry will be all too anxious to employ the labour in expanding production. But where should the provision be made? Can firms in the new towns cope with so large an annual influx of unskilled labour? The danger may well be that many school leavers will drift back to the relatively under-manned factories and offices within the conurbation itself—an ebbing of the tide which is now flowing so strongly. Judging by present experience, industry in the conurbation will not be reluctant to expand to receive any windfall of this type. In whichever parts of Greater London the labour is employed and ultimately settles, it must inevitably cement the whole more closely together.

Thirdly, the ageing of the population in the context of constantly rising standards of living may well create the greatest pressure of all. It is now possible to project the number of separate households likely to develop in the next 10–15 years. The London projections show that, assuming no migration, the 1956 population of the conurbation will generate an additional quarter million households requiring separate dwellings by 1971; 235,000 of these will be 'old' households which it may be difficult to persuade to move elsewhere. This new demand is additional to the estimated deficiency of a further quarter million dwellings existing in 1956. These figures appear alarmingly high. They take no account of the capacity of people to afford separate accommodation. But it would be unwise to ignore them on this account, for they are only the current and future reflection of long-standing trends which are obvious from the census reports. Moreover, current policy aims to facilitate house purchase and an adequate supply of houses has been an essential part of social policy since the war. It seems clear that housing demand will continue at a very high rate for a very long time and that, unless an entirely new approach is made to the renewal of existing urban areas, very substantial quantities of new land will be required to meet it. Renewal of old areas and development of new ones will both take place in fact, but the net effect must be a further consolidation of the greater regional conurbation.

CONCLUSION

The economic background of the Barlow Report is a thing of the past and planning based on it is equally out-dated. The expanding conurbation is the product of geographical and economic forces too powerful for man to reverse. He can only, within limits, direct them into convenient channels.

The hard core of the original conurbation has been contained with substantial success within its green belt so long as land remained available for development within it and planned reception areas provided safety valves beyond it. In and beyond the green-belt movements of population and industrial expansion have, with the aid of the motor car,

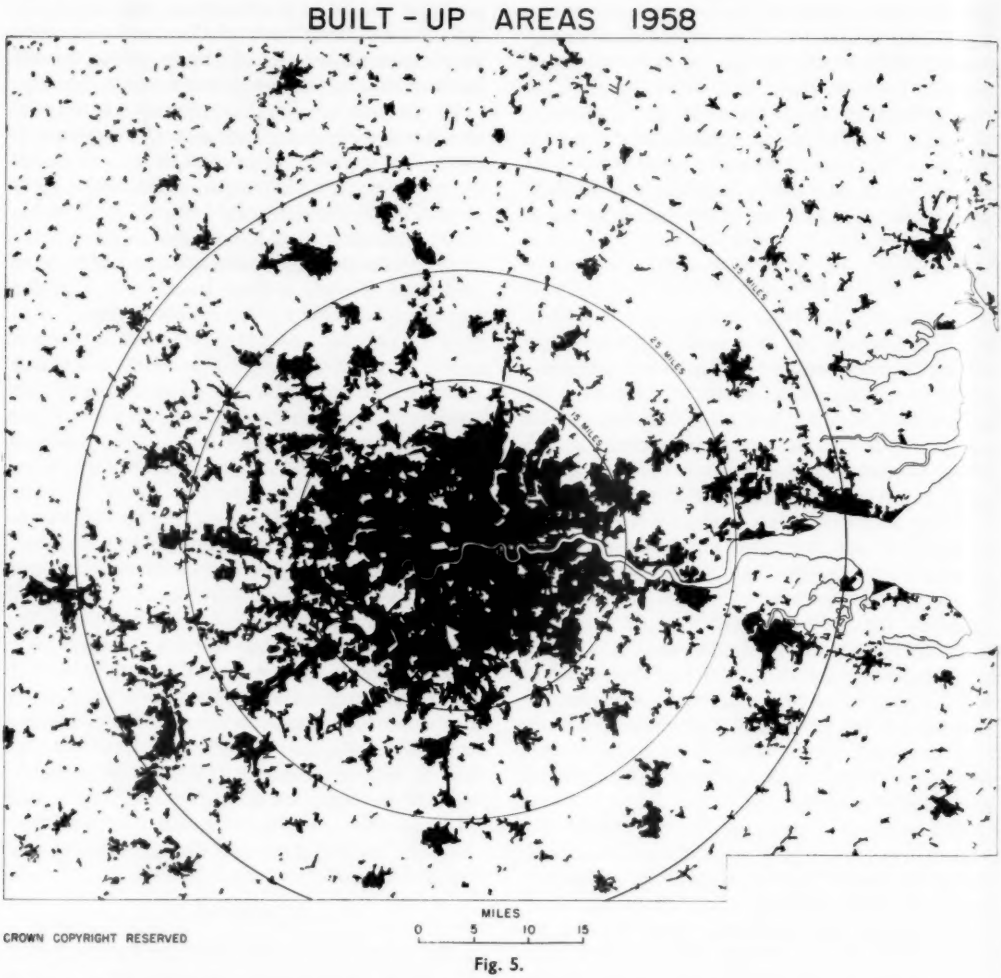


Fig. 5.

"Built-up Areas" include the residential, industrial and business areas of towns, villages and other closely developed settlements, together with the educational institutions, allotments and smaller open spaces which they envelop. Large industrial and service establishments in rural areas are also included. Golf courses and most airfields are excluded.

created an embryonic conurbation a hundred miles wide. This must inevitably consolidate still further.

The Abercrombie Plan and the Development Plans have their social and economic roots in the Barlow Report and a revised Regional Plan is urgently required to bring them into line with current realities. Such a revision must provide positive outlets and cannot be wholly restrictive. Unless a positive regional framework is provided, the strength of the geographic and economic forces involved threatens to break through the green belt and weld great new rings of urban development onto the core of the London conurbation as we know it today.

LOOKING AT science

The World of Oil—A Shell Exhibition

Mr. F. J. Stephens, Managing Director of the Royal Dutch Shell Group of Companies, opened the new Shell Exhibition 'The World of Oil' at a reception at Macmillan Hall, Senate House, London University, on March 21st.

This exhibition is designed to appeal to students of science and traces the story of oil from its origin to final distribution. After display at London University the exhibition will be shown at the Herbert Art School and Museum, Coventry, from April 25 to May 15; at the Science Museum, Birmingham, from May 23 to June 24; and at the University College of North Staffordshire University, Keele, from June 28 to July 8. At Keele the exhibition will also be seen by those attending the Annual General Meeting of the Museums Association.

This mobile display is arranged in twenty-five portable sections. Introductory displays show the use of oil in the home and in industry, and the whole process of oil formation, exploration and development is then traced in a series of carefully devised panels. Text and photographs are supported by examples of equipment and products, by displays of technique, and by the provision of simple and ingenious animation. Thus one may look at a gravimeter, or compare a sample of conventional oil transmuted by irradiation into a collection of lumpy particles with a specially prepared oil which retains all its lubrication properties after similar treatment. One may survey through lenses two

(By courtesy of Shell Film Unit—a still from the Shell film "The Oilman")

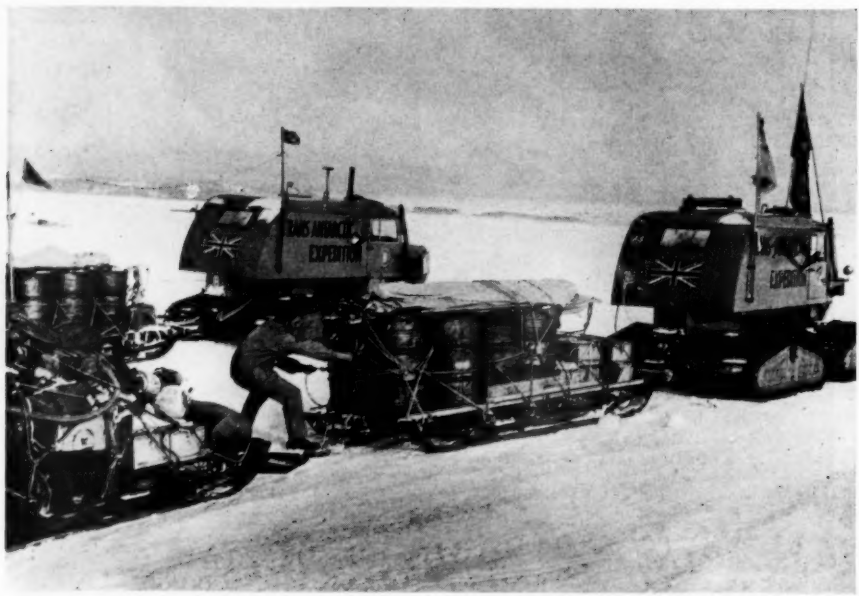
Using a gravimeter in Tunisia—an instrument displayed at the new Shell Exhibition, The World of Oil.

aerial photographs which become superimposed to reveal a three-dimensional study of the terrain surveyed. An illuminated coloured drawing of the deposition of decaying matter on the sea bed is vividly brought alive by a simple device which conveys the illusion of deposits falling through the water (a display which compares very well with cartoon film sequences made on this subject). The technique of seismic survey is illustrated by the use of flashing lights against a background illuminated drawing of rock strata and land surface, whilst the main features of oil distillation are shown in a model of a distillation column—the flow of by-products being demonstrated by evenly spaced bubbles flowing along small-gauge plastic tubes.

The notable feature of this exhibition is the great care which has been taken to present as much information as possible in simple visual terms. Text is reduced to a bare minimum and it is possible for the casual visitor to obtain not only a useful general picture of the world of oil but also to have some rough but basically accurate conception of its origins and the techniques used to exploit the mineral in the interests of man. How varied are the interests of the oil industry may be realised from one panel which shows that whilst world population is increasing at the rate of 50,000,000 a year one-third of all the crops grown in the world are destroyed before reaching the table. There is, therefore, abundant need not only for research into better methods of crop production but also into the destruction of pests which consume food so sorely needed by man. Insecticides and fungicides derived from oil play a notable part in man's struggle against pests.

The students for whom this exhibition is intended will learn a good deal from it. The educationist and scientist interested in techniques of visual presentation will witness an object lesson in vivid, informative and simple techniques which convey information much more effectively than the written word alone.

Requests for booking this exhibition should be made to Shell International Petroleum Co. Ltd., No. 1 Kingsway, London, W.C.2 (for attention of the Public Relations Division).



Another scientific activity to which the oil industry contributes is illustrated by this picture from The British Petroleum Co. Ltd. film "Antarctic Crossing".

BOOKS

Frontiers in Science. Edward Hutchings, Jr., Editor. (Allen and Unwin, 1960.) 362 pp. 25*s*.

This book is a collection of essays written at different times by members of the California Institute of Technology and originally published in the periodical, *Engineering and Science*. It is quite apparent, as Dr. DuBridge, the President of 'Caltech', writes in the preface, that it was never intended that they should form a unified whole. There is one group of eleven articles describing new discoveries in the biological sciences, and a second, comprising another nine papers, dealing with the physical sciences. Some of these are chatty, some earnest but interesting, one or two are written in technical non-English, a few are brilliant. Among these is a striking contribution by Sir Charles Darwin forecasting the future for the human race. I was also impressed by a strange and interesting article by Dr. Frank Brass abut the explosion of the volcano Krakatoa in 1883.

The last part of the book is made up of eleven more articles collected under the heading of science and society. Altogether they cover a wide field. 'The value of science', 'the significance of chemistry', 'the relation of science and religion'—these are samples of the titles. Again, the treatment is uneven. Here and there, 'the scientist'—or even 'we scientists'—is taken to be the chosen prophet of a new age, 'working for the betterment and happiness of human beings—nothing less and nothing more'. But again, some few contributions are of high excellence. Dr. Bowen, Director of the Palomar Observatory, argues with convincing persuasiveness that the study of astronomy gives us a true perspective of man's place in the universe, and Professor Feynman, discussing science and religion, writes something very much to the point for both scientists and religious men. But one of the most original and subtle contributions is, to my mind, the one by Dr. Elting Morison, now Professor of Industrial History at the Massachusetts Institute of Technology. He uses the events accompanying the introduction of 'continuous-aim firing' in ships at sea as a lesson on how best to learn to live with scientific change.

The growth of knowledge and the march of ideas make this a particularly difficult and dangerous age. The intention of *Frontiers in Science* to survey something of what is happening is admirable. And even if the book as a whole is not uniformly good, there are some excellent things in it.

MAGNUS PYKE

Principles for British Agricultural Policy. H. T. Williams, Editor. (Published for the Nuffield Foundation by the Oxford University Press, 1960.) 18*s*.

This report, sponsored by the Nuffield Foundation, and edited by H. T. Williams, is an attempt to determine the fixed points which should govern our agricultural policy in peacetime. What does history teach us about the character of our farming? What are the social arguments for a thriving countryside? What are the strategic considerations, underlying policy? How much food could we produce, if we tried, and what would it cost? What are the probable trends in demand?

There are no simple answers to these questions—indeed, the formulation of sound agricultural policy is one of the more thankless tasks of government. Mr. Williams does his best to simplify the issues. If his conclusions lack edge, it is because, if that is possible, almost too much thought has gone into them. The book has taken fifteen years to complete.

Mr. Williams' main conclusion is that our agriculture, for strategic reasons, should be as 'flexible' as

possible. What he means by this is a system based on the established, but far from general, practice of alternate husbandry. From the national point of view, it has the double advantage of keeping as much land as possible under the plough, fit for mobilisation if need arises, while in theory reducing costs through the better use of resources. As for the farmer, under a flexible regime, he will be on his toes, ready to exploit such opportunities as the market offers.

To some, this will seem like making out a case for mixed farming—often indistinguishable from muddled thinking. But Mr. Williams is not really against specialisation. He wants the farmer to specialise in flexibility. He could be right. Students of this year's White Paper on the Agricultural Price Review might reach a similar conclusion. But right or wrong, this book is well worth study, and the Nuffield Foundation is to be thanked for a handsome contribution of ideas on a complex and controversial subject.

An Introduction to Animal Husbandry in the Tropics. By G. Williamson and W. J. A. Payne. (London: Longmans, Green & Co. Ltd., 1959; New York: Longmans, Green & Co. Inc.) 48*s*.

There has long been a need for a book on tropical animal husbandry, a subject which, by comparison with crop husbandry, has received scant attention in the past. This book is intended to introduce to tropical students the elements of animal husbandry as they may be applied in the tropics and to indicate to those trained in temperate zones how the application of their theories may have to be modified to meet different conditions. With some reservations it is admirably suited to this purpose. It is very well produced and a feature of the book is the illustrations, a number of which are in colour. It is also noteworthy that a number of experts in special fields have contributed certain sections.

The book is divided into three main parts; the first deals with basic principles: effects of climate, health, nutrition and breeding. This is the most technical part of the book and a weakness here is the inclusion of the principles of Mendelian genetics which are not easily described in a dozen pages, whereas recent concepts in the application of progeny testing—one of the vital tools in animal improvement—is not sufficiently up to date. The chapter on nutrition is extremely concise and lucid.

The second part occupies just over half the book and deals with the husbandry of cattle, buffalo, sheep, goats, pigs, camels and poultry. Curiously there is no section on equines, particularly since the donkey is used extensively in parts of Africa as a beast of burden. This part of the book is excellent, but very little space is devoted to consideration of the problem of breeding policies, the pros and cons of selection of improved local types, or the selection of adapted and productive types from crossbred or imported stock. This is the major problem confronting the breeder of better dairy and beef cattle and it is only briefly discussed.

The third and shortest part of the book concerns animal products, i.e., milk and its products, and meat and carcass by-products. The chapter on the preparation of meat is of particular value since there is so little information on the subject. Both these chapters are contributed by experts in this field.

Of the three appendices, the first on 'The African Nomad' deserves special mention as it gives a most readable account of nomadism by two contributors with experience and knowledge of the subject.

This book deserves to be studied by all whose work lies in this field.

J. P. MAULE

Other Books Received

Materials and Rockets and Missiles. By R. G. Frank and W. F. Zimmerman. (Macmillan.) 31*s*. 6*d*.

Close Binary Systems. By Zdenek Kopal. (Chapman & Hall.) 105*s*.

Elements of Determinants, Matrices and Tensors for Engineers. By S. Austen Stignant. (McDonald & Co. (Publishers) Ltd.) 60*s*.

Introduction to the Study of Chemical Thermodynamics. By D. H. Everett. (Longmans, Green & Co. Ltd.) 28*s*.

Bananas. By N. W. Simmonds. (Longmans, Green & Co. Ltd.) 45*s*.

Exploding Wires. By W. G. Chace and H. K. Moore. (Chapman & Hall.) 76*s*.

Basics of Missile Guidance and Space Techniques. By Marvin Hobbs. (Chapman & Hall.) 63*s*.

Design for a Brain. By W. Ross Ashby. (Chapman & Hall.) 42*s*.

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